

Web Mapping on Land Cover Change of Kathmandu, Lalitpur and Bhaktapur District

Raj Ghimire, Sandesh Dhakal, Mira Sapkota, Yogesh KC, Reshma Shrestha*
rajghimire97@gmail.com, dhakalsandesh2055@gmail.com, sapkotameera5@gmail.com,
kcyogesh99@gmail.com, *reshma@ku.edu.np

KEYWORDS

Land Cover, Web Service, Thin Client, Web GIS, Web Interface

ABSTRACT

Land cover change is rapidly following path of environmental degradation, imbalance on ecosystem. Kathmandu, Lalitpur and Bhaktapur district has experienced a very high trend of urbanization and land use land cover change. Mapping this trend is absolutely necessary for sustainable development as well as conservation of the ecosystem. While there are desktop applications for making this mapping and analysis possible, upgrading to the web is the best possible way in order to interact with public as well as much easier way of data visualization, data analysis and data dissemination. This paper portrays the design and implementation process along with the visualization of a WebGIS platform via thin client architecture. A dynamic web map portal has been developed concerning the land cover change of Kathmandu, Lalitpur and Bhaktapur district. Among the several Free Open Source server software, OpenGeo Suite has been adopted for the project because it has a robust and flexible design that allows us to reliably handle and publish geospatial data. PostgreSQL/PostGIS, QGIS, Geoserver, Leaflet, and Apache Tomcat has been utilized as the web server in this suite. A fully functional website has been developed in order to host the maps and its components. WMS layers has also been published using Geoserver and styled as can be displayed on the web map portal. Leaflet plugins has been used with the help of which different tools like Zoom, Pan, Full Screen View and Distance Calculator are made available on the portal.

1. INTRODUCTION

1.1 Background

People are increasingly choosing to reside in cities and their surrounding areas because they are considered to offer better job

prospects, better healthcare, and a higher level of education. As a result, the global urban population reached 55 percent in 2018, and is expected to reach 68 percent by 2050 (Kookana, et al. 2020). The dynamics of land use/land cover (LULC) at broad scales have

been altered, either directly or indirectly, as a result of the fast expansion of built-up urban regions (Sarif et al. 2020). Considerable knowledge of gradual or abrupt natural changes, as well as factitious changes in the earth's surface, provides significant insight into the interplay between the natural environment and human activity (Bakr, et al. 2010). Taking in consideration of the tremendous amount of LULC change been speculated from the analysis of different research done by Ishtiaque et al. (2017), Rimal et al. (2018), Wang et al. (2020) and Li A et al. (2017), the project idea of portraying the land cover map prepared by different sources into an arranged, spectacular and user friendly dynamic web map portal emerged. While there are desktop applications for making this mapping and analysis possible, upgrading to the web is the best possible way in order to interact with public as well as much easier way of data visualization, data analysis and data dissemination. With the help of web mapping technology, user can collect information regarding land cover change between time period 2000 AD, 2010 AD and 2021 AD as well as perform some spatial analysis to an extent. The web map thus integrated into the web portal are also extractable through PDF following the idea of data dissemination to the public. The rapidly increasing urbanization and land use and land cover conversion from mostly agricultural land to commercial land by people in Kathmandu, Lalitpur and Bhaktapur made the necessity of the project research and web map portal design so that not only public but also concerned authorities like policy maker, urban planner as well as environmental specialists make necessary concerns and modifications in the way the land is being used and land cover being changed in the name of development and urbanization. For this particular project

we have used Land Cover Maps and not Land Use Maps. The project deals with mapping the land cover change of Kathmandu, Lalitpur and Bhaktapur Districts following the thin client architecture of WebGIS.

1.2 Objectives

The main objective of this study is to develop Web Map Portal Concerning the Land Cover Change of Kathmandu, Lalitpur and Bhaktapur District.

The secondary objectives are:

- To design a client server architecture framework.
- To create mapping functionality for the Web Maps with the help of Leaflet plugin.
- To publish WMS layers using GeoServer with a specific style.

1.3 Study Area

The study area of the project is Kathmandu, Lalitpur and Bhaktapur district of Nepal. The latitude of Kathmandu, is 27.700769, and the longitude is 85.300140 and lies on an altitude of 1337m. Similarly, Lalitpur is largest city of Nepal after Kathmandu and Pokhara, and it is located in the south-central part of Kathmandu Valley, a new metropolitan city of Nepal. The latitude and longitude of Lalitpur is 27.6588° N, 85.3247° E. Similarly, Bhaktapur is a city in the east corner of the Kathmandu Valley in Nepal about 13 kilometers'. Its latitude and longitude is 27.6710° N, 85.4298° E respectively. Because of its location in the Himalayas, its diverse physiographic diversity, and its status as one of South Asia's fastest expanding cities, this study region was chosen. It had a population of 1.11 million in 1991 which more than doubled to 2.52 million by 2016. (Sarif, et. al. 2020).

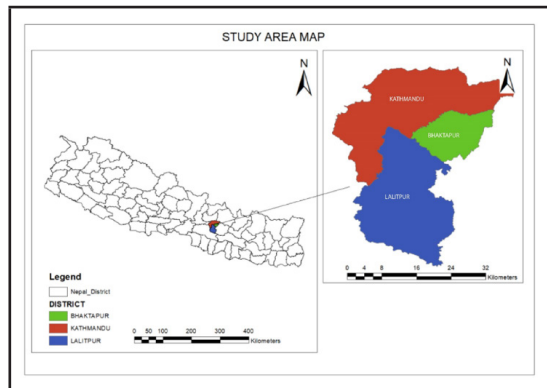


Figure 1: Study Area Map

2. DATASETS

The following were data used in the WebGIS platform.

- Land cover Map
- The Administrative Divisions Map
- The National Land Transport Network Map

The source of land cover maps was taken from ICIMOD for the year 2000 AD and 2010 AD with spatial resolution of 30 m. The source for the land cover map for the year 2021 was land cover map taken from Esri Living Atlas with spatial resolution 10m. The Administrative Divisions Map and the National Land Transport Network Map were downloaded from Open Data Nepal.

3. METHODOLOGICAL APPROACH

3.1 Design Process

Web GIS generally comprises of “three-tier architecture” which allows flexible separation of Logic Tier from the Data Tier and Presentation Tier. The three-tier model necessitates modular software with well-defined interfaces. When it comes to selecting the right web application, this modularity provides a lot of flexibility because each layer can be upgraded or changed independently of the others in terms of technology (Tiwari and Jain, 2013). This WebGIS platform is designed on the basis of thin client architecture.

The System Architecture consists of following functional part:

1. **Spatial database** that can provide random access to large data sets, query processing that understands spatial relationships.
2. **Desktop software** that can provide direct editing and visualization of data in the database. For data management, quality control, and ad hoc reporting.
3. **Cartographic map renderer** reads spatial data from the database, applies styling rules and outputs map images
4. **Application server** provides a programming framework for custom applications.
5. **Map tile server** stores pre-rendered image tiles and serves them up quickly to make maps refresh faster.
6. **Web map component** that can provide a map component inside a web browser.

Spatial Database facilitates with random access to large datasets as well as query processing that understands spatial relationships for example PostgreSQL, MySQL and others. The Database module is setup on the server to store spatial and a-spatial data. It mainly uses both the object-relational database management system PostgreSQL and its spatial information processing extension PostGIS. (Charoenbunwanon et al., 2016)

Desktop Software provides option for data visualization as well as direct editing and analysis of data in the database or any external data in the system, which can directly be analyzed by the admin or the data being manipulated through the web system with the help of client. GIS software is used to store, retrieve, manage, display, and analyze various forms of geographic and spatial data. GIS software allows user to create maps and other

visual representations of geographic data for analysis and presentation.

Rendering a map is the process of collecting raw geographical data and turning it into a visual map. The term is frequently used to refer to the creation of a raster image or a series of raster tiles, but it can also refer to the creation of vector-based map outputs. Cartographic Map Renderer reads spatial data from the database, applying some styling rules and outputs map images.

Application server provides a programming framework for custom applications. An application server is a type of platform middleware that is used nowadays. It's system software that sits between the operating system (OS) on one hand, external resources (such a database management system (DBMS), communications, and Internet services) on the other, and users' applications on the third. The application server's job is to act as a host (or container) for the user's business logic, allowing for easier access to and performance of the business application.

Map Tile Server stores pre-rendered image tiles and serves them up quickly to make maps refresh faster. A tiling server is GeoWebCache. It acts as a proxy between a map client and a map server, caching (saving) tiles as they are requested, avoiding repeated request processing and saving a significant amount of time. GeoWebCache is a standalone solution that may be used with various map servers and is integrated with GeoServer.

Web Map Component provides a map component inside a web browser. Maps contain a wealth of information, and understanding how to read and interpret them is essential. Every map has a set of features that make it easier to understand the information it contains. The title, direction and legend (or) key of symbol are the main necessary parts of a map.

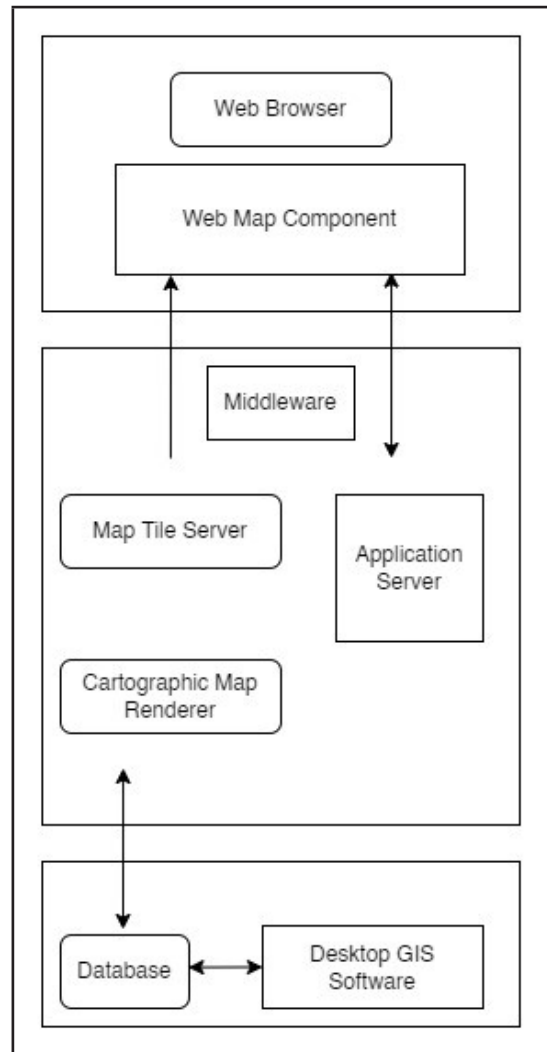


Figure 2: WebGIS System Architecture

The figure portrays the typical system architecture of WebGIS.

3.2 Implementation Process

3.2.1. Server Side Implementation

Geoserver was deployed under an Apache Tomcat servlet container. GeoServer is a server-side application that reacts to Leaflet requests from web browsers and generates geographical web objects dynamically. The Java-based program is the OGC's Web Feature Service (WFS) and Web Coverage Service (WCS) reference implementation. A workspace called Project was created in a GeoServer for the project. In this workspace, many stores

were built, and shape files were imported from local disks. Then, several layers were built and published, each with SLD styling and SRS boundaries established. The most common way to specify styling in GeoServer is to use XML SLD style documents. To indicate how GeoServer layers (featuretypes) should be presented, style documents are connected with them. A style document defines a single named layer as well as its user style. Metadata components for the layer and style can include a name to identify them, a title to show them, and an abstract to describe them in detail. One or more feature type styles exist within the top-level style, acting as "virtual layers" to determine rendering order. The next step involved preparing all of the layers with non-spatial information and creating a spatial data base using the PostgreSQL/PostGIS database. PostgreSQL and PostGIS manage the creation, maintenance, and use of a database that includes spatial and attribute data. To import a shape file into the loader utility program pgAdmin 4, PostGIS Bundle 3 for PostgreSQL (Shape-file and DBF Loader Exporter) was used. The attribute data was then obtained on the web page through the database utilizing a backend Node JS rest API. Using the PostGIS bundle, several layers are imported, each with an attribute table reflecting the land cover and the total area covered by the different land covers in different years, such as 2000, 2010, and 2021.

3.2.2. Client Side Implementation

The land cover datasets are served via Geoserver as WMS layers and the vector datasets as WFS layers. These layers are then rendered using Leaflet. The client uses the browser web to request spatial data from the server WMS. A completely functional and responsive website, as well as a map portal for viewing, sharing, and manipulating the web map, were created for this purpose. HTML,

CSS, and the Bootstrap framework were used to create the website. The OGC's GetMapRequest capability was used to provide spatial data from the mapping server to the user. Control functionality such as zooming in and out of the map, full screen map view, panning the map view, toggle between different layers as well as switching backdrop provided by Leaflet map providers, calculating distance between different locations, exporting map as a PDF in different map view modes such as Portrait, Landscape, Auto, and Custom was added using Leaflet, which is a JavaScript API for building rich Web-based geographic applications. Statistical data from the Landcover classes was included in the web page by producing a pie-chart and a column graph in Excel and Adobe Illustrator as can be seen on *Figure 5*. *Figure 3* represents the Web Map Portal as viewed on the browser of user while the *Figure 4* represents the attribute table fetched automatically from the PostgreSQL database.

The web map portal has a land cover map that illustrates the land cover change of Kathmandu, Lalitpur and Bhaktapur in the years 2000, 2010, and 2021, as seen in the diagram. On the right side of the screen there is the map gateway, which consists of a map container. The layer control button on the right side of the map container allows users to toggle between different map layers and backdrop map views using the leaflet map provider. The area of land cover classes in different time frames is included on left side of the screen. The area of the land cover classes is dynamic, as it is retrieved from the database using the attribute table of our map. Zooming in and out of the map, panning the map, calculating the distance between different locations within the map view, and exporting the web map as a pdf in Landscape, Portrait, Custom, and Auto modes are all included as different functionality in the map portal.

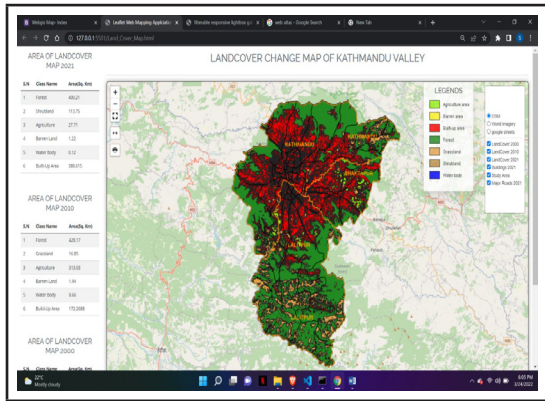


Figure 3: Web Map Portal

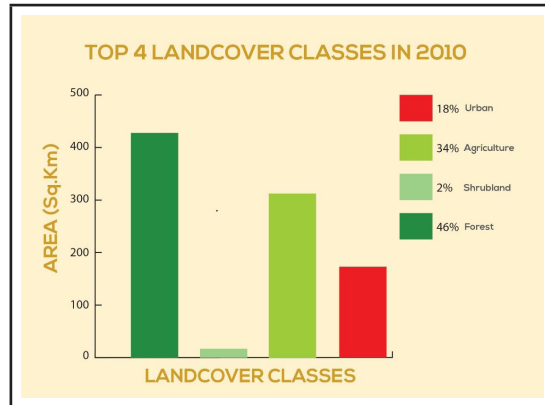


Figure 6: Column Graph Diagram of Land Cover Classes in 2010

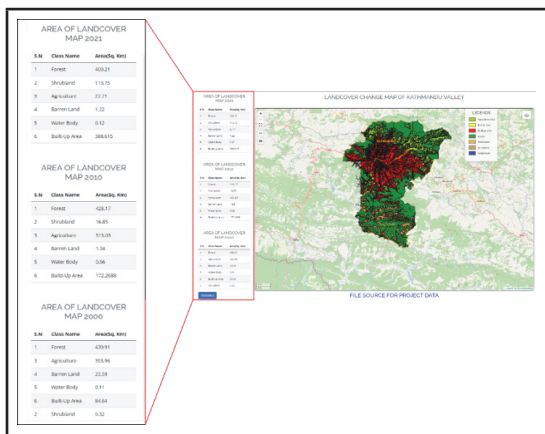


Figure 4: Attribute Table of Map

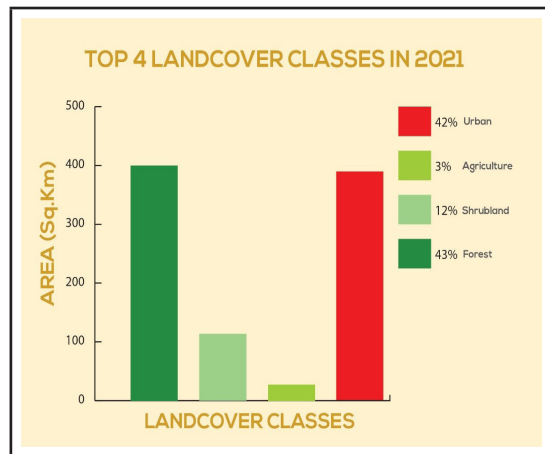


Figure 7: Column Graph Diagram of Land Cover Classes in 2021

The following three figures as in Column Graph Diagram (Figure 5, Figure 6, Figure 7) below show the top four land cover classes in 2000, 2010 and 2021 AD respectively. The X-axis represents the land classes and Y-axis represents the area in square kilometers.

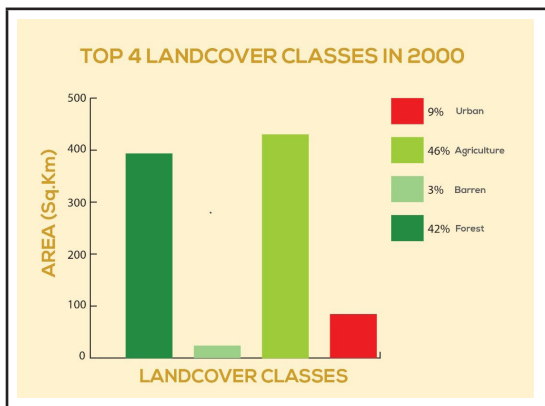


Figure 5: Column Graph Diagram of Land Cover Classes in 2000

The comparative Column Graph Diagram as in Figure 8 represents the statistical data of land cover classes. The urban land cover occupied 9% of total land area in 2000 AD, 18% of total land area in 2010 AD and 42% of total land area in 2021 AD. The agricultural land cover occupied 46% of total land area in 2000 AD, 34% of total land area in 2010 AD and 3% of total land area in 2021 AD. The shrub land cover occupied 3% of total land area in 2000 AD, 2% of total land area in 2010 AD and 12% of total land area in 2021 AD. The forest land cover occupied 42% of total land area in 2000 AD, 46% of total land area in 2010 AD and 43% of total land area in 2021 AD respectively.

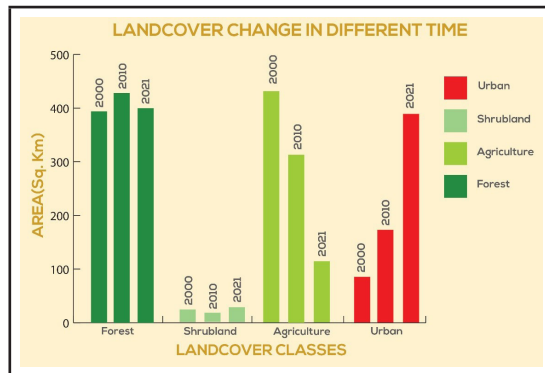


Figure 8: Comparative Column Graph Diagram of Land Cover Classes.

4. CONCLUSION

LULC change is rapidly following path of environmental degradation, imbalance on ecosystem. Kathmandu, Lalitpur and Bhaktapur has experienced a very high trend of urbanization and land use land cover change. Mapping this trend is absolutely necessary for sustainable development as well as conservation of the ecosystem. The web map portal helps in accessing the web maps with applied WebGIS cartography where users can visualize the web maps, browse through different mapping interface and download either raw map data or the maps with predefined cartographic components styled as visible on the portal. A fully functional website has been developed in order to host the maps and its components. WMS layers has also been published using Geoserver and styled as can be displayed on the web map portal. Leaflet plugins has been used with the help of which different tools like Zoom, Pan, Full Screen View and Distance Calculator are made available on the portal. The web mapping platform unlike paper based maps aims to raise discussion over the growing land cover change in Kathmandu, Lalitpur and Bhaktapur District as well as initiate startups for remedy to haphazard land use and land cover change in the Kathmandu, Lalitpur and Bhaktapur in the future with just few clicks and internet available.

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Author's Information

Name	: Raj Ghimire
Academic Qualification	: BE in Geomatics Engineering (KU)
Organization	: Geo Engineering Consultancy Pvt. Ltd.
Current Designation	: Geomatics Engineer
Work Experience	: 1 years
E-mail	: rajghimire97@gmail.com