National Land Use Zoning Dashboard – Harnessing Geo-informatics Technology for Seamless Land Management and Conflict Resolution

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Abstract

The National Land Use Zoning (NLUZ) exercise was conducted by the National Land Commission Secretariat (NLCS) in collaboration with other agencies of the Royal Government of Bhutan. The primary objective of this exercise was to harmonize all land uses on the ground and integrate spatial data across different agencies. Previously, such data had been created and archived separately within each agency. To accomplish this goal, a dedicated team was formed, and a baseline report was published in 2023. However, simply having a report did not fully support the objectives of the NLUZ. Therefore, an interactive dashboard was conceptualized to serve as a platform for integrating and visualizing all geospatial data. This dashboard will also provide analytical tools to guide decision-makers in the optimal utilization of the country's limited land resources. The development of the dashboard will utilize ArcGIS technology and will be customized using the ArcGIS Map SDK for JavaScript and the Calcite System Design.

1. Introduction

1.1 Background

For its entire baseline report creation, the National Land Use Zoning (NLUZ) Project collected data from multiple stakeholders that could be used to enhance any spatial-based decision-making in the country. NLUZ desires to achieve the following objectives (NLCS, 2023):

1. To establish a harmonized national land use system in the country;
2. To revalidate and delineate designated areas and macro land uses for better management;
3. To designate dysfunctional and functional land uses for any categories of development based on capability and suitability;
4. To establish a sound online database and maps of national zoning to facilitate a scientific-based decision-making process;
5. To make optimum, rational, and sustainable use of limited arable land by discouraging competition and avoiding land use conflicts;
6. To facilitate the establishment of spatial/ land use ordinances; and
7. To provide a scientific basis for governance and decision-making process.

The NLUZ dashboard aims to bring a geographic information system to a decision-support platform promoting the use of geographic information. This system will understand the decision maker, data users, data, and types of decisions to be enhanced and delivered.

2. Functional Requirement

The functional requirements describe the core functionality of the application. The requirements for this system are mentioned in detail below.

2.1 User Profile

The main application area for this system is of two levels, the details for each level are mentioned below. For common users who are browsers without registration to the system. The user should be able to only view the NLUZ maps and statistics. However, the user will not be able to perform any analysis and other advanced features of the system. The registered users should be able to view the data as well as perform the analysis available in the system.

2.2 Data Requirement

To make this system a data-driven dashboard, the need for reliable and standard data is crucial. The data requirements for this system include the majority of the fundamental geospatial datasets and a few others as well. In aligning the system development with the upcoming National Spatial Data Infrastructure (NSDI) and its importance for the geospatial community, the data for this system will be derived from or linked to the NSDI Data Portal. The zone classification with data attributes for each zone is mentioned below.

	Zones
Macro Zone 1	Agricultural Land
Macro Zone 2	Rural Settlement
Macro Zone 3	Sustainable Forest Management Area
Macro Zone 4	Nature Conservation Area
Macro Zone 5	Industrial
Macro Zone 6	Cultural Heritage
Macro Zone 7	Urban
Macro Zone 8	Rangeland
Macro Zone 9	Strategic Development

Table 1. Zone classification

In addition to the zone listed above, other data such as Land Use Land Cover (LULC), Right of Way / Buffer, and Fundamental Geospatial Layers will be connected to the system.

2.3 Application Requirement

The overall concept of the system is shown in Figure 1. The system will be developed using ArcGIS technology, particularly using the ArcGIS Map SDK for JavaScript. The key features of the NLUZ dashboard are explained below.

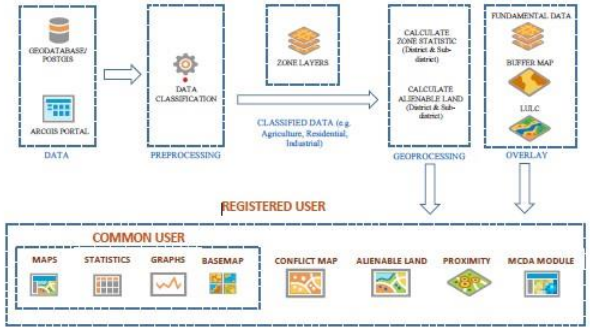

Figure 1: Conceptual diagram of the NLUZ dashboard.

2.3.1 Home Page: The landing page for the NLUZ dashboard is the home page. Home Page in general should be able to interact with the users and let them understand more about the capabilities of the system and its features. Some of the features available on the home page are the map and analysis tab. Apart from the already available data in the database, it enables users to add their data in various formats (.shp or .kml) into the system. It will also enable users to draw areas of interest on the system interface.

2.3.2 Information Analysis: The visualization styles and symbols defined should be incorporated into this system. It helps users select the data required for their project.

2.3.3 System Information: System information will consist of About and Download sections. The About section will provide information about the NLUZ, the stakeholders involved, and the technical partners in the development of the dashboard. Whereas, the download section will provide the users with options to download any report related to the NLUZ.

2.4 Spatial Analysis

The spatial analysis required for this project is briefly described below. Geometry analysis is the process of performing one or more operations on a point, polyline, or polygon to solve a geometric problem. You can use geometry operations to determine the spatial relationship between geometries, perform calculations such as creating a buffer, measure distance and area, and project geometries.

2.4.1 Overlay Analysis: Overlay analysis will include conflict and proximity analysis. This tool in the system will allow the users to get the conflict matrix between the zones and the right of way for the entire area or their area of interest. It calculates and displays the information regarding the area (in acres) that overlaps or intersects with other zones defined.

2.4.2 3D Visual Analysis: Utilizing the Digital Elevation Model (DEM) for the country, various analyses such as view shed and slope analysis could be conducted to meet the specific requirements of the users.

3. Non-Functional Requirement

The user interface (UI) is critical to any software system, including spatial decision support systems. A well-designed UI enhances user experience, facilitates efficient interaction, and contributes to the overall success of the system.

8. User-Friendly Design: Ensure the UI is intuitive and easy to navigate. Users should be able to access features and information without unnecessary complexity.
9. Clear Navigation: Implement a logical and straightforward navigation structure. Provide clear menus, buttons, and links to help users move seamlessly through the system.
10. Consistency: Maintain consistency in design elements, colour schemes, and terminology throughout the UI. Consistency helps users understand and predict the system's behavior.
11. Responsive Design: Ensure that the UI is responsive and adapts to different screen sizes and devices. This is particularly important for systems accessed on both desktop and mobile devices (Mobile-friendly interface for access on smartphones and tablets).
12. Prioritize Important Information: Highlight critical information and features prominently. Users should quickly find the most relevant data and tools for their decision-making process.
13. Feedback and Notifications: Provide feedback to users for their actions, such as successful data submissions or errors. Use notifications to alert users about important updates or changes.

While designing the system, it is important to make sure the system can handle large datasets and any increasing user loads in the future. Optimization of the performance of database queries and map rendering should be considered at the beginning of any system development.

4. Data Preparation

The dataset for the NLUZ comprises cadastral datasets from the National Land Commission Secretariat (NLCS) and additional datasets from other agencies. As outlined in Table 2, these datasets were validated, cleaned, and standardized following the methodology established by the Technical Working Group (TWG) (NLCS, 2023). The processed data are stored in a relational PostgreSQL database hosted on the NLCS server.

Thematic Layers		
Data	**Type**	**Source**
Nine Macro & Twenty Three Micro Land Uses	Polygon, Point	
LULC 2020	Polygon	NLCS
RoW & Buffers (Road Network, Powerlines, Flight Funnel, Heritage Buffer Zone, and Flood Hazard Map)	Polygon	
Demography	Attribute	NSB

Fundamental Geospatial Layers		
Data	**Type**	**Source**
Admin Boundary	Polygon	NLCS
Admin Points (Gewogs)	Point	NLCS
Airports	Point	DoAT
Bhutan Glacial Lake Inventory	Polygon	NCHM
Bhutan Glacier Inventory	Polygon	NCHM
Building Footprints	Polygon	CID, CGI
Cadastral and Thram Database	Polygon	NLCS
Community Forest	Polygon	DoFPS
Contour (1:50K & 1:25K)	Line	NLCS
Cultural Site Viewpoints	Point	DoCDD
DEM	Raster	NLCS
Existing Hydropower Plant	Point	DoE
Existing Mines	Polygon	DGM, NLCS
Feasible Airstrips and Helipads	Polygon	DoAT, NLCS
Flight Funnel	Polygon	DoAT
Forest Management Unit	Polygon	DoFPS
Geographical Names	Point	DLGDM
Gyalsung Visibility Area	Polygon	NLCS
Heritage Buffer Zone	Polygon	DoCDD
Heritage Conservation and Village Zone	Polygon	DoCDD
Heritage Sites (Nye Atlas)	Point	NLCS
Institutions	Point	NLCS
Key Biodiversity Area	Polygon	DoFPS
Mini Hydel	Point	BPC
Paro Flood Hazard Map	Polygon	FEMD
Payment for Ecosystem Services	Polygon	DoW
Potential Recharge Area	Polygon	DoW
Powerline_Buffer (RoW)	Polygon	DoE
Powerlines	Line	DoE
Prospective Mineral Zone	Polygon	DGM
Protected Area	Polygon	DoFPS
Protected Chhuzhing	Polygon	DoA
PSMP Dam	Point	DoE
PSMP Powerplant	Point	DoE
PSMP Reservoir	Polygon	DoE
PSMP Waterway	Line	DoE
Ramsar Site	Polygon	DoW
Road	Line	DoST, NLCS
Road Buffer (RoW)	Polygon	DoST
Samtse Flood Hazard Map	Polygon	FEMD
Satellite Imagery (Google, OSM & Bing)	Raster	Open Source
Tashigang Flood Hazard Map	Polygon	FEMD
Water Sources	Point	DoW
Waterways	Line	DoE

Table 2. Spatial Datasets.

4.1 Data Mapping

The data were stored as respective layers, as acquired from the various agencies, and required mapping to assign feature layers to their respective zones. The NLCS zoning team facilitated this data mapping process, as illustrated in Table 3.

File Name	Field	Micro Zone	Macro Zone
cadastralreclassified_nlcs	WHERE "reclass" = "agriculture lease land"	Agricultural Leased Land	Agriculture
	WHERE "reclass" = "chhuzhing"	Chhuzhing	Agriculture
	WHERE "reclass" = "institutional land"	Institutional Land	Rural Settlement
	WHERE "reclass" = "kamzhing"	Kamzhing	Agriculture
	WHERE "reclass" = "manufacturing and production industry"	Manufacturing and Production Industry	Industrial
	WHERE "reclass" = "religious sites"	Religious Sites	Cultural Heritage
	WHERE "reclass" = "residential land"	Residential Land	Rural Settlement
	WHERE "reclass" = "service industry"	Service Industry	Industrial
	WHERE "reclass" = "tsamdro"	Tsamdro	Rangeland
communityforest_dofps		Community Forests (CF)	Sustainable Forest Management Area (SFMA)
existingmines_dgm_nlcs	WHERE "reclass" = "manufacturing and production industry"	Existing Mines	Industrial
flightfunnel_doat		Flight Funnel	Right of Way/Buffer
forestmanagementunit_dofps		Forest Management Unit (FMU)	Sustainable Forest Management Area (SFMA)
glof_nchm		Glacier Lake Outbrust Flood	Hazard and Risk
hcv_wwf_dofps		Other Effective Area-based Conservation Measures (OECM)	Nature Conservation Area (NCA)
heritagebufferzone_docdd		Heritage	Right of Way/Buffer
heritageconservation&villagezone_docdd		Heritage Village	Cultural Heritage
keybiodiversityarea_dofps		Other Effective Area-based Conservation Measures (OECM)	Nature Conservation Area (NCA)
ncrluc_cndp_dhs		Human Settlement Plans	Strategic Development
parofloodhazard_femd_dhs		Rain Induced Flood	Hazard and Risk
paroregionalstrategyarea_rcud		Human Settlement Plans	Strategic Development
paroregionalstrategicsites_rcud		Human Settlement Plans	Strategic Development
pes_dow		Significant Watershed	Nature Conservation Area (NCA)
potentialrechargearea_dow		Significant Watershed	Nature Conservation Area (NCA)
proposedip_doi		Prospective Industries	Strategic Development
prospectivemineralzone&miningarea_dgm		Prospective Industries	Strategic Development
protectedarea_dofps	WHERE "zone" = "Biological Corridor"	Protected Area (PA)	Nature Conservation Area (NCA)
	WHERE "zone" = "Botanical Park"	Protected Area (PA)	Nature Conservation Area (NCA)
	WHERE "zone" = "Buffer zone"	Protected Area (PA)	Nature Conservation Area (NCA)
	WHERE "zone" = "Core zone"	Protected Area (PA)	Nature Conservation Area (NCA)
	WHERE "zone" = "Multiple use zone"	Protected Area (PA)	Nature Conservation Area (NCA)
	WHERE "zone" = "Transition zone"	Protected Area (PA)	Nature Conservation Area (NCA)
protectedchhuzhing_doa		Protected Chhuzhing	Agriculture
psmpdam_doe		Prospective Industries	Strategic Development
psmppowerplant_doe		Prospective Industries	Strategic Development
psmpwaterway_doe		Prospective Industries	Strategic Development
psmpreservoir_doe		Prospective Industries	Strategic Development
ramsar_dow		Wetland	Nature Conservation Area (NCA)
roadbuffer_dost		Road	Right of Way/Buffer
samtsefloodhazard_femd_dhs		Rain Induced Flood	Hazard and Risk
strategicUrbanZone_dhs		Human Settlement Plans	Strategic Development
tashigangfloodhazard_femd_dhs		Rain Induced Flood	Hazard and Risk
thimphuregionalstrategyarea_rcud		Human Settlement Plans	Strategic Development
thimphuregionalstrategicsites_rcud		Human Settlement Plans	Strategic Development
transmissionline_row_doe		Powerline	Right of Way/Buffer
watersources_dow		Significant Watershed	Nature Conservation Area (NCA)

Table 3. Data Mapping.

4.2 Publish Data

To use feature layers in a web application, they must be published on a server. ArcGIS Server or GeoServer are commonly used for this purpose. Given that the NLCS has an ArcGIS Enterprise license, the data will be published to ArcGIS Server. There are two configurations for setting up ArcGIS Server: as a stand-alone ArcGIS Server or a federated ArcGIS

Server. When publishing web services from ArcMap or ArcGIS Pro to ArcGIS Enterprise, the map content is transformed into web GIS resources through service runtime. The behavior and functionalities of these services depend on the compatibility between the desktop application and ArcGIS Enterprise (Esri Australia, 2023). Therefore, it is crucial to verify the version compatibility of the software used.

Based on the data mapping, a project file is created in ArcGIS Pro to assign feature layers to their respective zones, ultimately facilitating the publication of the map as a map service. The data visualization chart, as shown in Figure 2, was used to style the feature layers accordingly.

Figure 2: NLUZ data visualization chart.

The results of loading the feature layers in ArcGIS Pro and applying styles using the data visualization chart are shown in Figure 3. To publish the data, the database must be registered on the ArcGIS Server. ArcGIS Pro facilitates the registration and publication of data. If your server is a stand-alone server, you need to connect to it directly. Alternatively, if your server is federated, ArcGIS Pro allows you to connect by logging in using your ArcGIS Portal credentials.

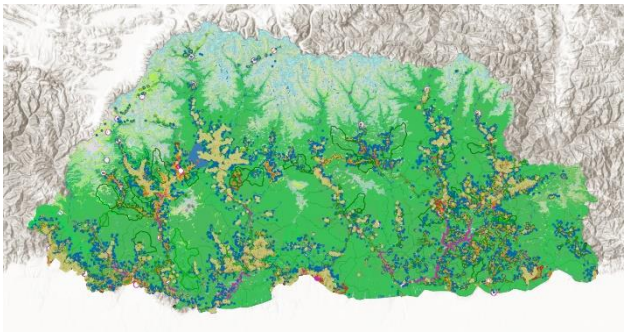

Figure 3: Map with style as seen in ArcGIS Pro.

Donoghue (2023) highlights another option: FASTAPI, a modern web framework for building APIs with Python. This framework allows for direct connections to Postgres to create feature services without the need to publish the services.

4.3 Create WebMap

To create a web application, you must first create a web map, which is an interactive display of geographic information arranged in layers (Global Forest Watch, 2022). A web map in ArcGIS Enterprise or ArcGIS Online functions similarly to an mxd file in ArcGIS Desktop. It allows you to add data, style, and customize the map according to user requirements before embedding it in a web application. To make the web map publicly accessible, it must be shared with "Everyone (public)." Otherwise, users will require credentials to access the web map.

5. Application Development

Esri offers several options for creating web applications, including ArcGIS Web AppBuilder, ArcGIS Dashboards, and ArcGIS Experience Builder. These tools are available in both ArcGIS Enterprise and ArcGIS Online (AGOL), featuring easy drag-and-drop interfaces to customize web applications. For a more robust and customizable solution, the ArcGIS API for JavaScript provides all the necessary tools to create highly scalable and efficient applications (Total APIs, 2023).

5.1 User Interface Design

In the digital age, user interface design (UI) has become crucial for the success of digital products—whether websites, mobile apps, or software applications—by enhancing both aesthetics and the overall user experience (Lozé, 2023). It is always recommended to start developing an application or a system with a good UI design and to facilitate this, there are numerous UI design applications such as Figma, wix, and many more. The NLCS’s zoning team developed a simple UI for the NLUZ dashboard in wix, as shown in Figure 4. This UI design will serve as a blueprint for the web developer to develop the application.

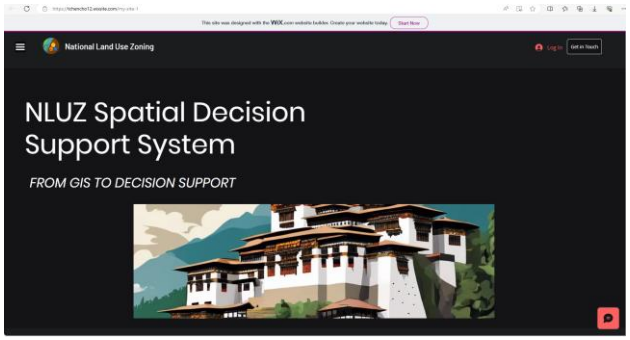

Figure 4. A screenshot of NLUZ Dashboard UI Design.

5.2 Component of Web Application

The web application will have multiple pages such as home, about, map, download, and project. The idea is to have two levels of users– a common user will have view access only and a registered user will have both view and analysis access. Registered users will be provided with credentials to access the application.

5.2.1 Home: This will be the landing page of the application with a brief description of the application and the rationale behind the development of the application. It will provide an account tab to provide users with sign-in or sign-up options and a forgot password option to securely reset the password, thereby further enhancing the user experience and security measures.

5.2.2 About: All captions must be centred directly beneath the illustration. Use single spacing if they use more than one line. All captions are to be numbered The About section will offer a brief overview of the NLUZ program. It will highlight the stakeholders who contributed to the inception and execution of the NLUZ initiative, alongside acknowledging the technical supporters involved in the development of the system.

5.2.3 Map: This will be the main page of the system serving as the central hub for visualizing feature layers and zones, offering users the flexibility to toggle between different layers and basemaps to enhance visualization. Additionally, users will have the option to input data for analysis against the designated zones, enabling the generation of conflict maps. Furthermore, the system will facilitate the export of generated information in various formats, including maps, graphs, and charts, for integration into reports. To streamline this process, predefined templates will be available within the application, empowering users to efficiently create comprehensive reports tailored to their needs.

5.2.4 Download: The download page will allow users to download NLUZ reports, data, and maps.

5.2.5 Project: This page will provide users the capability to establish their personalized folders, providing a dedicated space to store and manage their work. Users will have the flexibility to create new projects within their folders, as well as add and delete projects as needed, enabling efficient organization and maintenance of their workspaces.

5.3 Software Requirement

Various technologies and software will be utilized in the development of the application, with two distinct sets of requirements identified for the NLUZ dashboard development.

The primary map component will leverage the ArcGIS Map SDK for JavaScript, an Esri JavaScript framework designed to construct engaging web applications that maximize the potential of data through interactive user experiences and impressive 2D and 3D visualizations (ArcGIS Maps SDK for JavaScript, 2024). Additionally, the calcite design system, a comprehensive suite of designs and development resources provided by Esri, will be employed to craft an aesthetically pleasing, user-friendly, and cohesive application experience with minimal effort (Esri, 2024).

The other component will necessitate a more general web application development approach, such as utilizing a framework like Bootstrap. Bootstrap stands as the premier HTML, CSS, and JavaScript framework for crafting responsive, mobile-first websites (w3schools, 2024).

5.4 Use Case

Given the multitude of potential applications for the National Land Use Zoning (NLUZ) Dashboard, it is prudent to focus initial exploration efforts within the National Land Commission Secretariat (NLCS), specifically within the Land Management Division (LMD). This division plays a pivotal role in managing state land by facilitating activities such as leasing, exchange, and substitution for various developmental purposes. Ensuring that these activities align with designated land use zones is paramount to avoiding conflicts and promoting sustainable land management practices.

Historically, instances have arisen where land allocated for development encroached upon critical biological corridors, leading to land use conflicts. The implementation of the NLUZ Dashboard presents an opportunity for the LMD to mitigate such occurrences. By incorporating the dashboard into their decision-making processes, the division can proactively assess potential conflicts between proposed land releases and designated zones. This preemptive analysis not only safeguards against inadvertent land use conflicts but also facilitates informed decision-making by providing detailed reports highlighting areas of potential conflict.

Moreover, the NLUZ Dashboard can serve as a valuable tool for the government in identifying suitable land parcels for release, thus optimizing land utilization while minimizing environmental impact. By leveraging the dashboard's capabilities to analyze spatial data and assess compatibility with designated zones, the government can make more informed decisions regarding land allocation, fostering sustainable development and minimizing land use conflicts.

6. Conclusion

In conclusion, the development of the National Land Use Zoning (NLUZ) Dashboard represents a significant step forward in leveraging geo-informatics technology for the seamless management of land resources and resolution of land use conflicts. Through the integration of advanced mapping capabilities, data analysis tools, and user-friendly interfaces, the NLUZ Dashboard offers a comprehensive solution for stakeholders involved in land management and planning.

The implementation of the NLUZ Dashboard addresses the complex challenges associated with land use planning and conflict resolution by providing a centralized platform for visualizing land use zones, analyzing spatial data, and

generating actionable insights. By fostering collaboration among various stakeholders and streamlining decision-making processes, the dashboard empowers policymakers, land managers, and communities to make informed decisions that promote sustainable development and mitigate conflicts.

As demonstrated by its features and functionalities, the NLUZ Dashboard has the potential to revolutionize land management practices and promote harmony between competing land uses. However, its effectiveness ultimately depends on continued support, collaboration, and adaptation to evolving needs and technological advancements.

References

NLCS, 2023: National Land Use Zoning – A Baseline Report.

Esri Australia, 2023: Compatibility between ArcGIS Desktop applications and ArcGIS Enterprise. https://esriaustraliatechblog.wordpress.com/2023/01/03/compatibility-between-arcgis-desktop-applications-and-arcgis-enterprise/ (22 May 2024).

Donoghue, R., 2023: Web Mapping Apps with Postgres + ArcGIS without ArcGIS Enterprise. https://www.linkedin.com/pulse/web-mapping-apps-postgres-arcgis-without-enterprise-rhys-donoghue/ (22 May 2024).

Global Forest Watch, 2022: Create a web map on ArcGIS Online. https://www.globalforestwatch.org/help/mapbuilder/guides/create-web-map-arcgis-online/ (22 May 2024).

Total APIs., 2023: Using frameworks. https://totalapis.github.io/guide/using-frameworks/index.html (22 May 2024).

Lozé, S., 2023: 11 Useful Benefits of Good User Interface Design. https://www.linkedin.com/pulse/11-useful-benefits-good-user-interface-design-adzmode/ (23 May 2024).

ArcGIS Maps SDK for JavaScript, 2024. https://developers.arcgis.com/javascript/latest/ (23 May 2024).

Esri, 2024: Calcite Design System. https://developers.arcgis.com/calcite-design-system/ (23 May 2024).

w3schools, 2024: Bootstrap 3 Tutorial. https://www.w3schools.com/bootstrap/ (23 May 2024).