Cadastral Base-Map Management in Indonesia

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SUMMARY

The implementation of Geographic Information Systems (GIS) has been greatly impacted by the advancement of information technology. In Indonesia, the government recognized the potential benefits of using GIS for land-related activities and began using the technology while conducting a comprehensive and systematic land registration project (called PTSL) in 2017. The project itself has been developed and adjusted following the country's needs. Trials on methods of spatial data acquisition were held and collaborations were also carried out to get a complete cadastral base map throughout Indonesia.

The urge of modernizing the Land Administration system led to the development of standards and procedures for the online management of cadastral base maps. The primary goal of this development is to improve the accessibility and efficiency of data interoperability, where the existing data are expected to provide greater benefits for the public interests. By 2021, the plan on developing a digital scheme for cadastral base map management was first executed. As the initial step, compiling the existing imageries data and map were taken into action to make them easily accessible through web services. The following year – 2022, another development was implemented in the system to adapt to the changing policy on cadastral survey methods.

The system – like any other system, still needs to be developed and adjusted following the needs of the stakeholders and users. The development of managing cadastral base-map in Indonesia and the efforts carried out to achieve the current improvement are elaborated on in this paper. The challenges and how to tackle the issues related to system development were also mentioned – along with some further recommendations and resumes of the papers in the final section, thus they can be helpful both as a practical experience or basic knowledge for developing such a system.

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1. INTRODUCTION

Indonesian governments have declared the implementation of digital transformation to provide an excellent service for the community. The intention for actualizing e-governance in the governmental body also happened in the land administration sector. Along with the development of technology, the procedures for administering land aimed to give a better quality of service to the public have also been transforming. Computer and Information Technology has been disrupting the process, starting from the initial document registration, data acquisition, data processing, and also data management.

In realizing digital transformation in land services, the Indonesian government has established a digital transformation roadmap that is embodied in a strategic plan in the land and spatial planning sector – including the acceleration of validation and data collection (the Republic of Indonesia, 2020). To support the goal of legalizing assets or comprehensive land registration in 2022, the government continues to seek various ways to accelerate its achievement, including collaborative efforts with various parties.

The limited coverage of base maps has always been one of the obstacles in efforts to accelerate land registration in Indonesia. This limitation is caused by the existing system, both the regulatory system which limits the freedom to provide spatial data, as well as the accelerated condition where the level of land data production downstream is already very high, while the production of base map data as initial supporting data cannot yet be provided massively. In its development, the land base map has undergone adjustments in terms of methodology and data sources (see figure 1). This change in methodology also has implications for changes in the culture of data management, from previously managed analog because the maps were hardcopy maps, to developing into digital data – especially after the digital transformation announced in 2020.

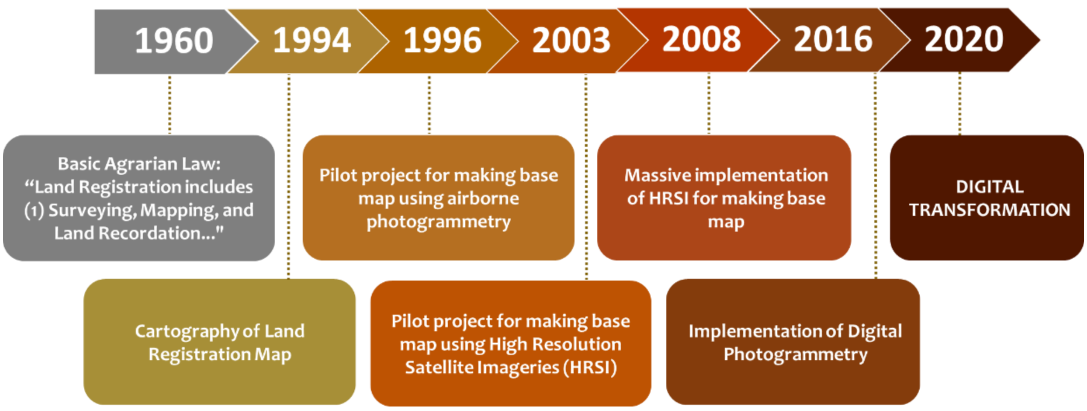

Figure 1. Development of cadastral base map in Indonesia

2020 is the first year that a digital base map data management design has been implemented. The governance in question is not only regarding data storage but also regarding data exchange to the data updating mechanism. At that time, the existence of systematic land registration activities in Indonesia resulted in a high need for base maps, causing an increase in requests for base map data. Thus, the base map data, which at that time was stored digitally but still being managed manually, resulted in the intensity of data requests being carried out manually and taking quite a long time (see Figure 2 of the process of requesting base map data in 2020).

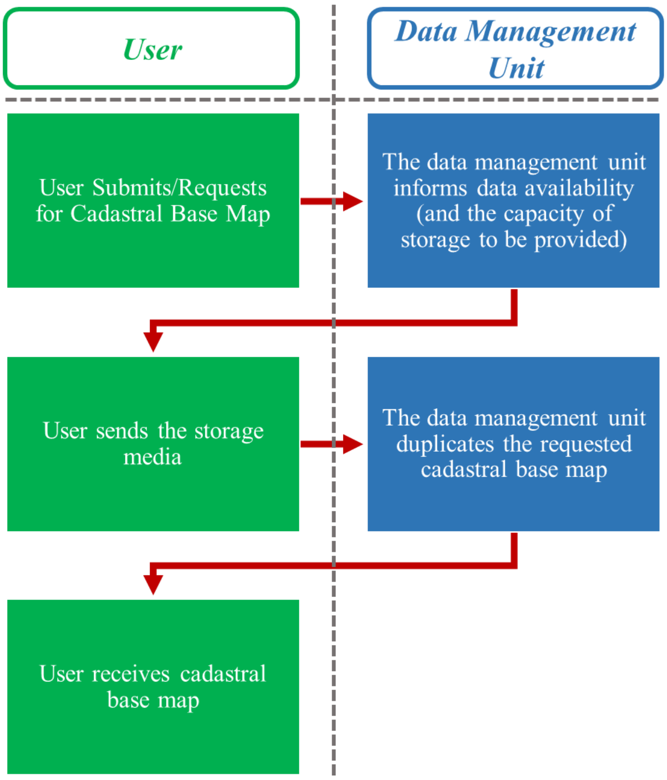

Figure 2. The old method of data exchange

2. ESTABLISHMENT OF DIGITAL BASEMAP MANAGEMENT

In 2018, the government of Indonesia developed a standard and procedure for the online management of base maps, which served as the first legal document for developing online base maps in the ministry. The main goal of this development was to improve the accessibility and efficiency of map sharing. Previously, base maps were typically delivered to regional offices via external hard disk, which took much work. With the new online platform, it was hoped that users could quickly and easily access the maps they needed for their work.

In 2021, a platform called the base maps database and information system was developed – along with surveyor, equipment, and forest boundary databases and systems. These four modules were integrated into a single application to realize the digital transformation where the standard and operational procedures are implemented and improved, using the utilization of GIS in land-related activities in Indonesia. The base maps database and information system were specifically designed to compile any available imagery from across the country and make it easily accessible through web services for use in these activities.

The features of this base maps module are summarized in Table 1. These features allow users in regional offices to look up the available base maps suitable for their needs and submit a data request. Once the request is approved, they can download the data using the file transfer protocol (FTP). Users in regional offices, along with head office administrators, can also add new base maps by using the upload feature. Once the data and its essential metadata are verified, the base maps are added to the availability list.

Table 1. Base maps module functionality

Sub-module	**Functionality**
Base maps information	Index of availability
	Availability recap table
	Query by type, year of acquisition, scale, and location (draw or upload AoI)
Base maps storage	Upload and download imagery (satellite, airborne, drone)
	Upload and download line maps
	Data verification
Administration and support	Data request report
	Data utilization report
	Tutorial
	Contacts

However, typical new systems, challenges, and obstacles were encountered during development. Our first design made the system serve more or less as a data repository where the original raster tag image file format (.tiff/.tif) is stored in the storage server. Though the data is cropped into a particular map sheet index, a large amount of memory is still required to store the data. Moreover, our storage server capability cannot handle large imagery data as it has a low data transfer rate resulting in a long time needed for upload and download. To address this problem and improve the overall functionality of the platform, a second development was conducted in 2022.

The redevelopment follows a software development life cycle (SDLC) of planning, creating, testing, and deploying an information system (Kneuper, 2017). Requirements analysis in the planning phase includes identifying needs and problem formulation, which look for alternative solutions. Our requirements were driven by the need for a much faster display and more responsive base map service. The proposed solution was to make base map data into tile images. The next step is designing the application. The purpose of this stage is to have a clear picture of the appearance and interface of the software, which a team of programmers will then execute. This process will focus on building data structures, software architecture, interface design, and each procedural algorithm's internal and external function design. The designed architecture is shown in Figure 3.

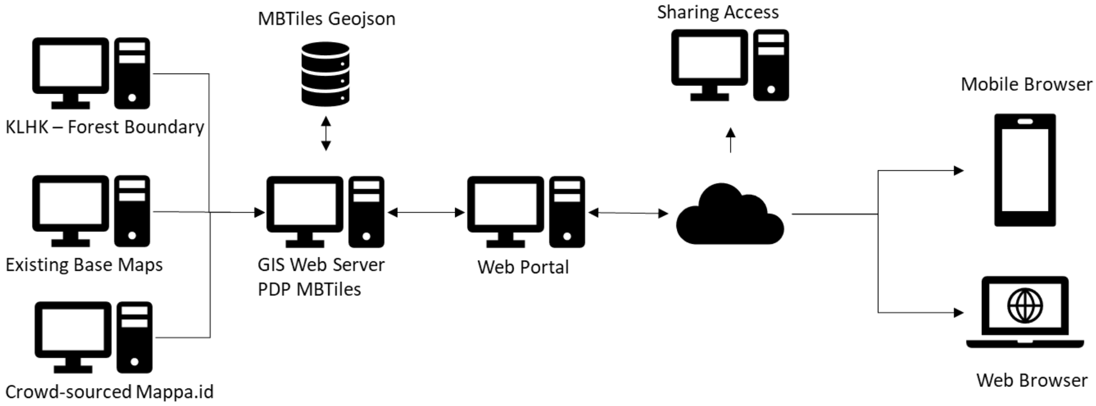

Figure 3. Designed system architecture

Our design translates user requirements into five functional sub-modules (feature groups). Most of these feature groups are accessed from the landing page, as visualized in Figure 4. The display framework is intended as a prototype plan for functional displays of application sub-modules. Subsequently, in the following part, each sub-module will be elaborated as follows:

a. Login sub-module

The first sub-module is user login. Users are classified into three categories: administrators, internal staff as internal users, and external users for public users. Internal users utilize a single-sign-on authentication method using their employee data that has been previously implemented. External users are required to register and log in using their email.

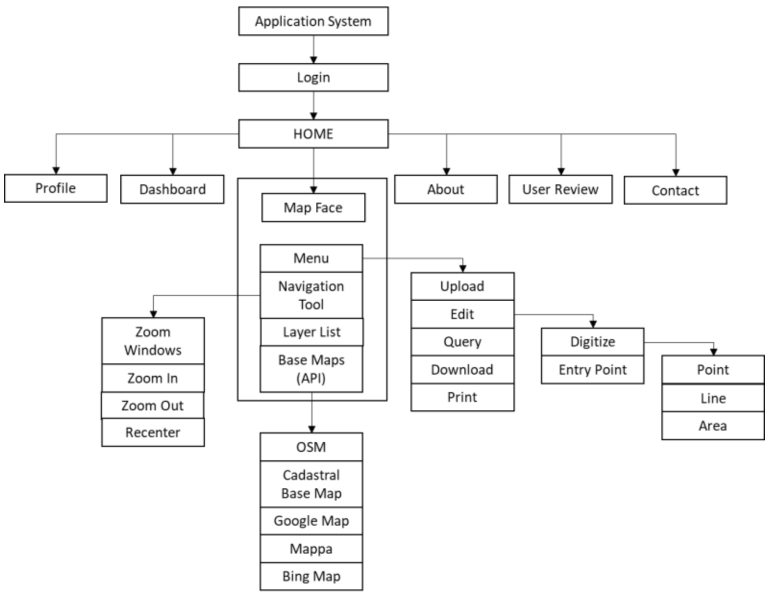

Figure 4. Display framework of the base map module

b. System administrative sub-module

This sub-module deals with the role and the authority of each user. Five roles may be given to the users: administrator, contributor, verifier, and validator, as well as regular users. Administrators are given the authority to manage users and the database as well as access to all features in the system. The following three roles are dedicated only to internal users. The survey and mapping staff all over Indonesia has access to upload their base map data as a contributor.

Regional offices nominate verifier and validator, and they serve as two-step verification for newly added data by the contributor. They must check data compliance with the standard format and, most importantly, check its metadata quality agreement. Once data are validated, they will be displayed on the system. Regular users' authority is limited to downloading data and providing reviews and ratings of the data.

c. Database management sub-module

Our design requires converting *.tiff data into smaller packages of tiles, which are stored in a hierarchy allowing for quick and efficient rendering of base maps at different zoom levels without storing and transmitting all of the data. Some standard file formats for these tiles include MBtiles, GeoPackage, and TileJSON. Our specifications for tiling the imagery data are listed in Table 2 where we use MBtiles format and divide imagery into two specific rules. Clouston and Peterson, 2014 elaborated on the method of making maps into chunks of smaller map sheets to speed up access to map visualization - a method that was introduced by Google in 2005.

An aerial orthophoto, which generally has a better geometric resolution, is tiled at 16 to 21 zoom levels, while satellite imagery is tiled at 12 to 19. In addition, it was designed to upload and display vector data such as toponyms, administrative boundaries, forest boundaries, transportation, and water features. It can also display another map like OpenStreetMap and crowdsourced aerial orthophotos from Indonesian start-up mappa.id and old Google-sourced satellite imagery.

Table 2. Tile image specification

File format	.mbtiles		
Number of bands	3 (RGB)		
Mbtiles format	.jpg (75%)		
Type of Imagery	**Resolution**	**Zoom Level**	
Orthophoto (aerial vehicle)	<0.25 m	16 – 21	
Satellite imagery	0.25 - 0.75 m	12 – 19	

Each tile of the Mbtiles map comes with its respective metadata consisting of at least contributor data, time of acquisition, geometric resolution, and accuracy. It is intended that every surveyor who will use the base map understand and be aware of the quality of the base map, so they can use it with caution to land the land parcels.

d. System visual information and publication sub-module

This sub-module is a group of display frameworks in application systems intended to display data/information on map pages/faces and provide users access to data publication (download), including facilities for performing data/location search (query). Our main page is displayed in Figure 5.

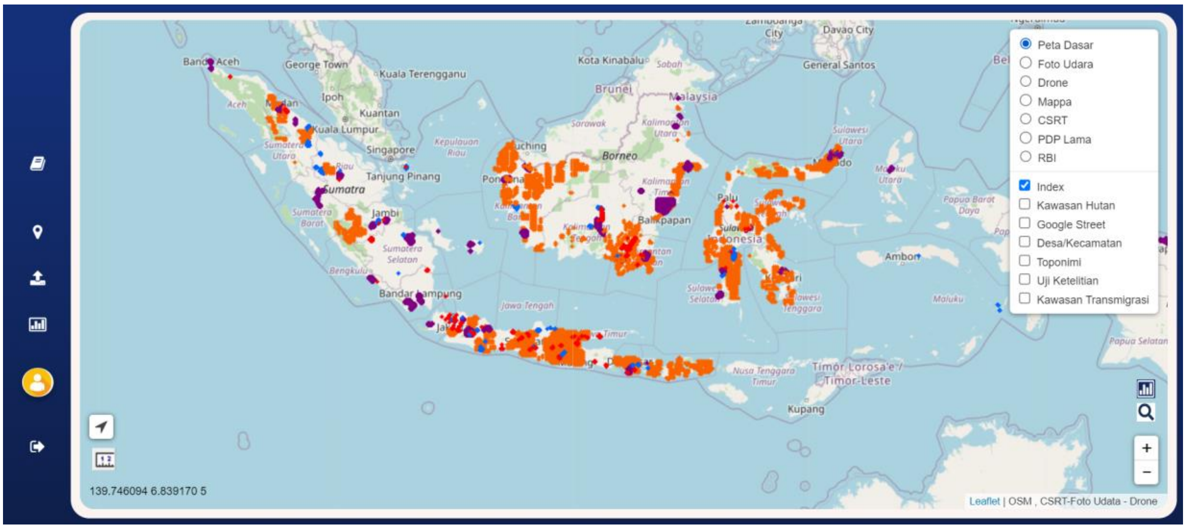

Figure 5. Main page

The default main page displays the base map availability index. Each color represents data type, i.e., orange for satellite imagery, purple and blue for aerial orthophoto (airborne and UAVs), and red for crowd-sourced data. Other layers, such as forest areas and administrative boundaries, can be displayed.

Regular users can wander through the index, and once specific zoom levels are reached, the tile data will be displayed. Otherwise, users can query by location to look up their desired data. If a specific index is clicked, its metadata will pop up, and users can download data and give ratings for this particular data. Should there be two types of data available in the location or one type of data with different acquisition times, the system will provide a comparison of those data.

Figure 6. Visualization of metadata

e. Report sub-module

This sub-module records and displays statistical data on the utilization of this application system which functions as a report to several stakeholders, such as the number of visits, downloads, and coverage data.

After completing the coding phase, this platform is thoroughly tested by conducting a running test. This ensures that the related application modules can run and produce excellent and valid output. Testing is done using several case scenarios carried out by users, such as multitasking, multiuser, performance, system resilience, and compatibility testing. The results of this test are expected to detect problems that arise earlier before being used by end users. The procedure performed in this test is as follows:

a. Installing the new system into the operational environment. While this process is running, a global test will be carried out, including system testing, user acceptance testing, and the installation process on client hardware;
b. Conducting system trials based on the methods compiled in software quality product planning, namely load testing, stress testing, regression testing, and penetration testing;
c. Simulating and monitoring the operating system within the ATR/BPN environment.

3. FUTURE DEVELOPMENT PLAN

While the grand design of further development of this online cadastral base map management system is yet to be established, this system needs to be maintained functional to support land registration activities in Indonesia, especially since 2023, when there is a change in land parcel data acquisition methods using photogrammetry. Surveyors in regional offices are encouraged to provide base maps by capturing aerial photos using drone/unmanned aerial vehicles (UAVs). A spike in new base maps data is unavoidable and thus requires a reliable and responsive application.

This year, experts in webGIS development are hired to improve the application’s overall stability. They were also tasked with developing the interface of the portal based on user experience; ensuring that the site can function optimally, and exercising control from the server, system, and database side. In addition, a new cloud server storage is planned to be deployed. Our calculation showed that existing land base maps require a storage capacity of 3.4 Terrabytes. If it is assumed that there are 2.5 million hectares of new data a year, it will require a data storage capacity of 2.2 Terabytes per year or 6.6 terabytes in 2025. Thus, the total need for storage in the early stages requires a minimum capacity of 10 Terrabytes. This new cloud-dedicated server storage will address our hardware limitation and provide better data security, and a fast access and responsive application.

In the long run, we are eager to extend this platform to display 3-dimensional data (see Figure 7). This relates to the need to visualize space rights above and below ground level. The increasing number of high-rise buildings and infrastructure, such as roads and rails, above and below ground level adds to the complexity of registering rights. 3D modeling of these objects is necessary, and delineating rights boundaries in space must be well-defined. In this case, the platform's ability to display 3-dimensional data is a pre-requisite.

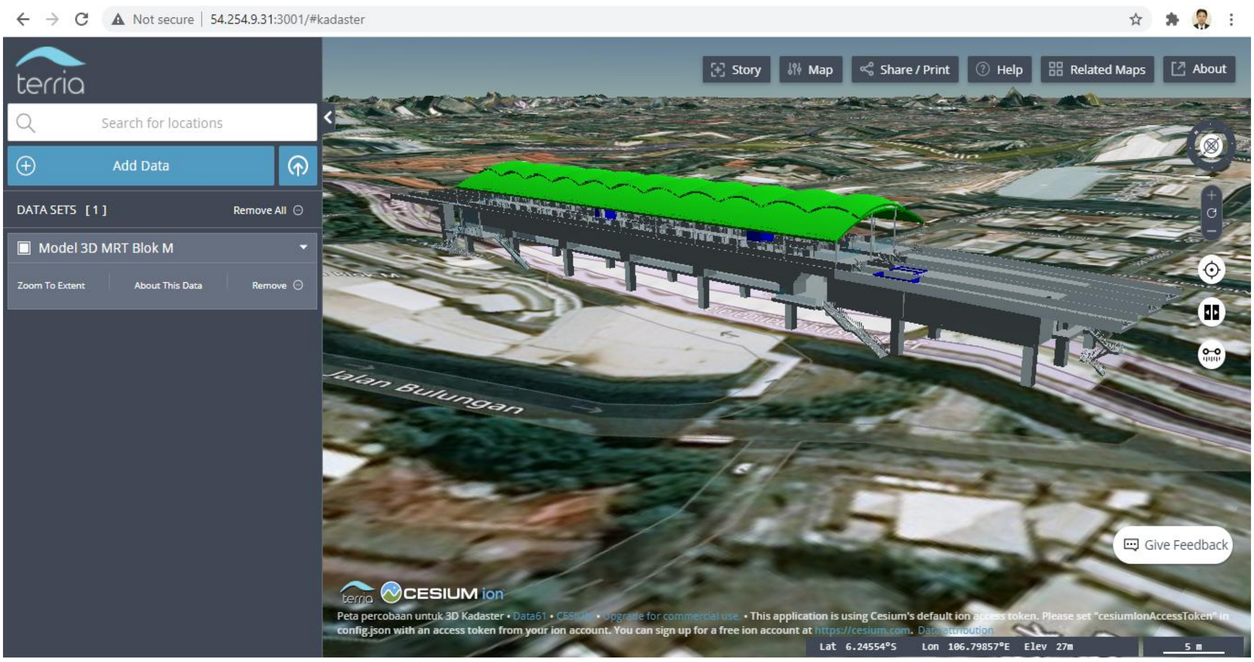

Figure 7. Dummy visualization for a 3D modeling for future development

4. CONCLUSION

In conclusion, the Indonesian government has been implementing digital transformation in land administration to provide better services to the public. The government has established a strategic plan and roadmap for digital transformation and has been collaborating with various parties to achieve the goal of legalizing assets or comprehensive land registration in 2022. The development of the base map system has undergone adjustments in methodology and data sources, and a digital base map management system has been established to improve the accessibility and efficiency of map sharing. However, challenges and obstacles were encountered during the development process, and a second development was conducted in 2022 to address these issues. The new design made base map data into tile images to achieve a much faster display and more responsive base map service. Overall, the digital transformation in land administration in Indonesia has shown significant progress, and the establishment of the digital base map management system has provided a useful tool for land-related activities in the country.

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