Harmonisation of Geospatial Data in the Process Evaluation of Land Utilisation Suitability Based on Cadastral Land Parcel

Diyono,[1] Sutanta, H.,[2] Ummah, M. H.,[3] Widjajanti, N.[4*] and Atunggal, D.[5]
Department of Geodetic Engineering, Faculty of Engineering, Universitas Gadjah Mada, Jln. Grafika No. 2, Yogyakarta (55281), Indonesia, E-mail: diyono@ugm.ac.id,[1] herisutanta@ugm.ac.id,[2] muhammadhidayatulummah@mail.ugm.ac.id,[3] nwidjajanti@ugm.ac.id,[4] dediatunggal@ugm.ac.id[5]
*Corresponding Author

DOI: https://doi.org/10.52939/ijg.v21i4.4071

Abstract
One of the fundamental components of Indonesia's Land Administration System (LAS) that still needs to be harmonised is the problem of ideal map geometry, namely spatial units of cadastral land parcels. The LAS has four key functions: land tenure, land value, land use, and land development. This study addresses the harmonisation of Geospatial Data (GD) for land development administration involving spatial planning. This spatial element is crucial in sustainable spatial planning for dynamic regional development. This study harmonises GD to synchronise the spatial planning map based on the cadastral map. We harmonises geometrical aspects of spatial planning maps and cadastral maps using Unmanned Aerial Vehicle (UAV) imagery and field survey as the base map. The analysis reveals that more than 25% of land parcels intersect with multiple spatial zoning maps. To address this, the study uses a hierarchical logic method to unify each cadastral land-parcel's spatial planning. Using cadastral land-parcel-based spatial zoning, the suitability of land utilisation in the study area is dominated by the limitedly and conditionally class, covering an area of 1,023,584 m^2(40.72%). There is significant difference in area calculation of spatial utilisation suitability when using the original spatial map and cadastral land parcel, with a confidence level of 95%. This discrepancy arises from the different of map framework between zoning and cadastral maps. High-quality cadastral land parcel maps are essential to enhance the quality of spatial zoning maps and support sustainable LAS. The findings of this study underscore the importance of GD harmonization and quality improvement within the LAS framework, highlighting the impact of this harmonization on spatial zoning maps in Indonesia.

Keywords: Cadastral Map, Geospatial Data, Harmonisation, Land Utilisation, Zoning Map

1. Introduction

Cadastral data harmonisation is required for various Land Administration System (LAS) purposes. LAS is the process of determining, recording, and disseminating information on land ownership, value, utilisation, and planned utilisation to manage rights, restriction, and responsibility over the land [1] and [2]. Within the LAS scope, land management activities consist of physical and legal aspects. The physical aspect of the LAS consists of (a) land use planning, (b) issuing land permits, (c) issuing location permits, and (d) organising land acquisition for development [3] and [4]. Based on the authority of the management institution, the legal and physical aspects of land are carried out by different institutions even though the object is the same in the form of an expanse of land [5][6] and [7]. Looking back at the vision of the 1996 Bogor Declaration, building a Land Information System (LIS) is necessary to facilitate harmony in land management due to differences in authority [8]. The statement remains valid today. Further, LIS can be enhanced into Land Information Infrastructure (LII) to support the realisation of sustainable development [4] and [9]. LII is a framework that facilitates the service and exchange of cadastral geospatial data between institutions on the realisation of modern LAS [10]. The availability of LIS based on LII can also facilitate better data access, exchange, and integration that supports land information management [11] and [12]. However, in practice, the operationalisation of LII in Indonesia on the spatial data side still has challenges, one of which is due to the unavailability of harmonised spatial data [13].

ISSN: 1686-6576 (Printed) | ISSN 2673-0014 (Online) | © Geoinformatics International

Federation International of Surveyors (FIG) has developed the Land Administration Domain Model (LADM) standard, ISO 19152, to harmonise the exchange and sharing of cadastral information. The LADM is a conceptual model representing the combination of land management components, such as land tenure, land value, land use, and land development. It requires a foundation of data on the geometric elements of the land parcel [14]. In Indonesian context, having harmonised land data in the land information system is also beneficial in realising the one map policy stipulated in Presidential Regulation Nr. 27/2014 and Nr. 09/2016. The responsibility of delivering accurate cadastral data lies on the Ministry of Agrarian Affairs and Spatial Planning - National Land Agency (ATR-BPN) [15]. However, the element of land administration which has the highest availability in Indonesia is land tenure [16] while the provision of accurate and complete cadastral map is an ongoing process. The land development aspect, implemented into spatial planning, still needs to be fully aligned with the land parcels. The cadastral data and spatial planning map are managed by different organisations using different standards [3]. This situation creates data incompatibility. The integration between them can provide comprehensive insight into the boundaries of land ownership and regulation on land use [17]. Data from the spatial plan and the cadastral system should be shared with citizens, including landowners and businesses. This aims to ensure that the utilisation of land conforms to the spatial plan developed by the appropriate authority [18]. Compatibility between cadastral data and spatial plan maps can stimulate the dynamic development of urban areas [19]. The compatibility is expected in the synchronised geometric and legal attributes of land parcel data and the geometric and characteristic features of the spatial plan [20] and [21].

Geospatial Data (GD) inconsistency between cadastral and spatial datasets arises from the lack of coherence in syntax, structure, and semantic elements [22]. Specifically, syntactical disharmony lies in the structure and data format inconsistencies, which diminishes its compatibility when utilised within various software [23]. Schematic or structural discord refers to a conflict arising during the database design when the data hierarchy is expressed and assigned to physical entities of the real world [24]. Moreover, semantic discord refers to the different names used for the same phenomena or objects [25]. To enable the integration of data from diverse sources, metadata is needed to assess the compatibility of the data [26][27] and [28]. Several studies have been developed to detect inconsistencies in spatial data. A simple logic model was developed to measure the level of spatial data inconsistency in many practical scenarios [29]. The research also defines a procedure for cleaning up inconsistencies in all primitive instances of points, lines, and areas. The method needs identification inconsistencies and classification of them into initial, lithographic, vectorised, and maintenance cadastral data classes of errors [30]. Further the inconsistencies were corrected using observation of cadastral documents and matching them with objects condition in the field, using orthophoto and Cadastre Triangulation Model (CTM) technique [31]. According to the study, the CTM method is suitable for cadastral systems that are not presented digitally.

Harmonisation of spatial plans and cadastral data is to make them ready for exchange and integration within the scope of land information infrastructure [32]. Furthermore, harmonisation can support land information governance effectively and efficiently, allowing the efficient utilisation of data [33] and optimisation of regional planning. Spatial data harmonisation benefits various application domains, such as the unification of boundary maps in the European Union [22] and the border between Germany and the Czech Republic [34]. Thus, regional planning can be conducted optimally. Research on GD harmonisation was previously conducted by a team that sought to unite the maps associated with the problem of boundaries in the European Union [22]. The study implemented the Infrastructure for Spatial Information in Europe (INSPIRE) standard for GD harmonization in the context of syntax, structure, and semantic. Likewise, the harmonisation of the GI database for the state border between Germany and the Czech Republic has been done by [34]. The research used a semantic harmonisation approach to make the boundaries between the two countries interoperable following the Open Geospatial Consortium (OGC) format. Both studies are part of the HUMBOLDT project activities that contribute to developing Spatial Data Infrastructure (SDI) in Europe. In the methodological aspect, [35] conducted semi-automatic harmonisation of spatial data through semantic web design and ontology. ISO 19109 (general rules) and ISO 19107 (geometry representation) were the basis for web development. The system plan is represented as a Unified Modeling Language (UML) diagram by creating system schema elements, domain ontology schema, and ontology mapping.

Similarly, [36] adopted domain ontology to harmonise spatial data related to urban planning, resulting in two mechanisms that bind the relationship between data and ontology.

The first mechanism is a filtering technique for categorical data sets so that data sets can be mapped to specific ontology sub-class concepts. The second mechanism is a unit conversion of numerical data. Hence, standardisation that defines the complete data model elements [37] and aggregation [38] can improve spatial data interoperability. This research aimed to implement a new method to harmonise cadastral data and spatial plan maps, which integrate geometric elements and assess the utilisation of the spatial plan. The agreement of the zoning map of the spatial plan and the cadastral data was evaluated. Any disagreements, such as gaps, overlaps, or improper intersect, were identified and analysed. Conformance with administrative boundaries was also checked. The harmonisation was conducted by adjusting the original zoning map into land parcel-based representation. Further, it assessed the land utilisation within each designated type for both categories. The chi-square test was applied to ascertain the results of this land utilisation evaluation.

2. Data and Methods

2.1 Study Area and Data Source

The study area is the Mantrijeron District of Yogyakarta City, Indonesia. The district consists of three urban villages: Mantrijeron, Kedongkiwo, and Suryodiningratan, and it covers an area of 268.41 ha (Figure 1). Three primary data sources were used: the Detailed Spatial Plan (RDTR) of Yogyakarta City for the year of 2021-2041, a cadastral land parcel map, and unmanned aerial vehicle (UAV) imagery produced in 2023. The RDTR has a zoning map at a scale of 1:5,000, which was obtained from the Land and Spatial Planning Office of Yogyakarta City. The cadastral maps, at a scale of 1:5,000, were received from the Yogyakarta City Land Office. The original 1:1,000 has been changed to 1:5,000. The UAV imagery with 5 cm spatial resolution was obtained from the Public Works, Housing, and Settlement Area Office in Yogyakarta City. The data that were used in this study is represented in Figure 2.

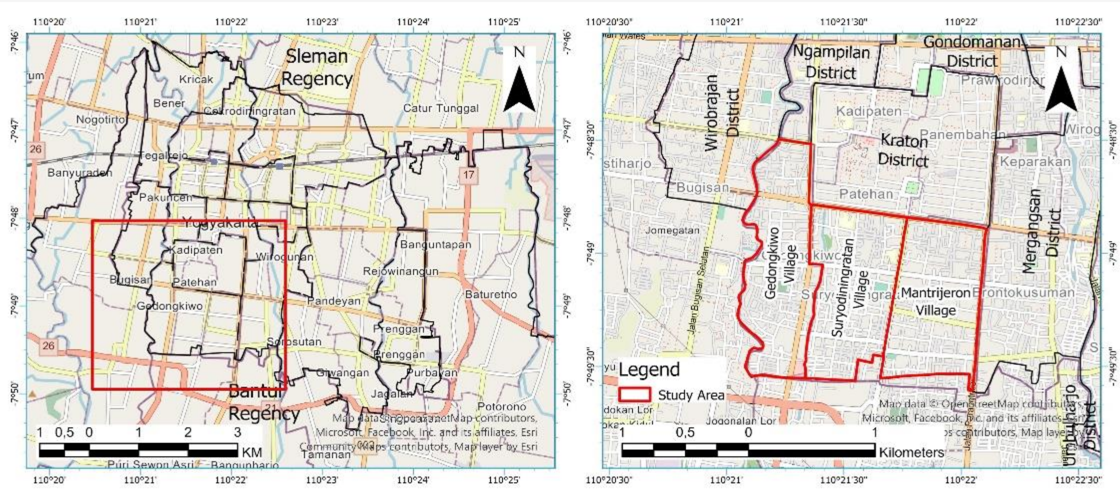


Figure 1: Mantrijeron District, Yogyakarta City, Indonesia
(source: Geoportal of Yogyakarta City)

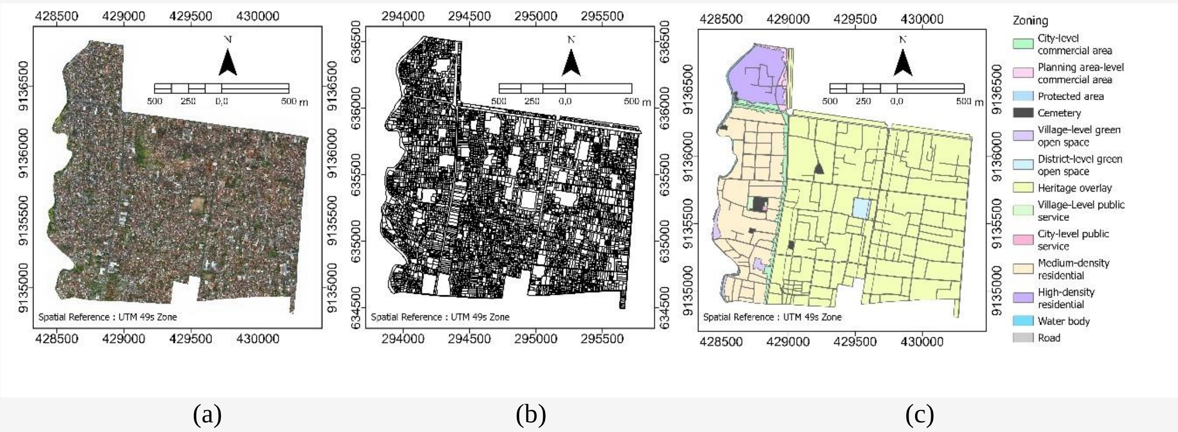


Figure 2: Data used in the study; (a) UAV imagery; (b) cadastral land-parcel; (c) RDTR zoning map

ISSN: 1686-6576 (Printed) | ISSN 2673-0014 (Online) | © Geoinformatics International

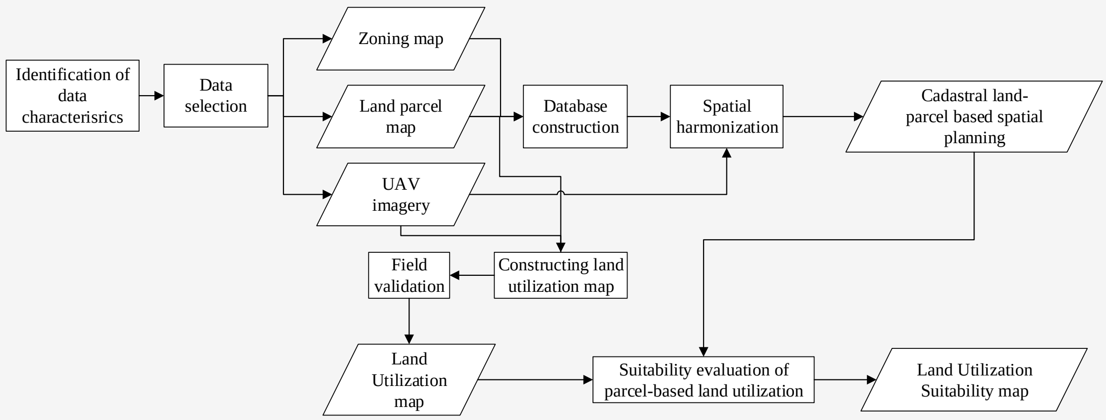


Figure 3: Flowchart of geospatial data harminisation between cadastral land parcel with spatial planning

2.2 Methods

The research steps are presented as a flowchart depicted in Figure 3. This research consists of four main stages, namely, (1) identification of inconsistencies between RDTR zoning map and cadastral map, (2) harmonisation of RDTR zoning map and cadastral maps, (3) development of proposed zoning map by cadastral map, and (4) analysis of land use suitability of the harmonised map. The following sections elaborate on these main research activities.

2.2.1 Identification of inconsistencies between RDTR zoning map and cadastral map

The identification of inconsistencies is the first step in harmonisation between geospatial datasets. In this research, inconsistency refers to the geometric difference between RDTR zoning and cadastral maps. The following aspects were evaluated: location, dimension, area, shape, and proportion. This evaluation was conducted by overlaying two datasets to identify the characteristics of conflicts that may occur. Having identified the geometry conflict, the harmonised datasets can be created at a later stage. The harmonised datasets will support realising the one map policy in the land administration domain.

2.2.2 Harmonisation of RDTR zoning map and cadastral map

The harmonisation process consisted of aligning the spatial reference and coordinate systems between the two spatial datasets across two distinct thematic domains, defining the geometry of land parcel boundaries, and aligning the boundaries of the zoning map zoning with the land parcel boundaries. The geometry alignment was cross-referenced with aerial photographs and ensured logical consistency. The alignment result was subsequently transformed into a spatial dataset based on cadastral land parcels. Here, the spatial join operation was used. It integrates attributes of two spatial layers based on their spatial relationships. A unification process is used when a land parcel intersects with multiple spatial planning zone areas. To address these issues, this research proposes a hierarchical logic model to unify the spatial planning of each land parcel.

The calculation is conducted for the area with an intersection between the zoning map and land parcels that exceed more than 5% of the total area of that parcel. This threshold assumed that the confidence level of the map products is 95%. Therefore, the proportion of 5% area to each area of the cadastral land parcel significantly influences spatial planning regulations. The hierarchy was generated considering the accessibility aspect and rigidity priority. The highest hierarchy is for spatial planning zones along the main roads, called the accessibility aspect. The commercial zone (trade and service) has the highest proportion as the along-the-road zone. Its flexibility in regulations makes it the highest priority. The rigidity of the zoning regulations refers to the number of restrictions in the specific spatial planning directives, as presented in Table 1. The number of restrictions in the rigidity-based hierarchy system was determined by the number of "X" symbols in the ITBX matrix in each spatial planning zone, as detailed in the next section. This system is analogous to the more "X" symbols, the more rigid the regulations imposed on the spatial planning zone. The prioritisation of determining the most suitable planning zones according to Table 1 was done using the flowchart presented in Figure 4. First, we checked whether the parcel was located along the road or river. Secondly, the parcel was tested to see whether the intersected area exceeded 5% of the parcel. Further, the process continued with testing on zones according to the sequence of Table 1.

ISSN: 1686-6576 (Printed) | ISSN 2673-0014 (Online) | © Geoinformatics International

Table 1: Unification priority for multi-spatial planning zones on one cadastral land parcel

Spatial Planning Zone	Number of Restrictions	Priority	Additional Information
Commercial (trade and service)	4	1	Accessibility
Planning area – commercial	4	2	priority aspect
Protected area	207	3	Regulation rigidity
Cemetery	203	4	priority aspect
City-level green open space	143	5	
Village-level open space	140	6	
Cultural heritage	52	7	
Village-level public service	27	8	
City-level public service	27	9	
Medium-density residential	22	10	
High-density residential	22	11	

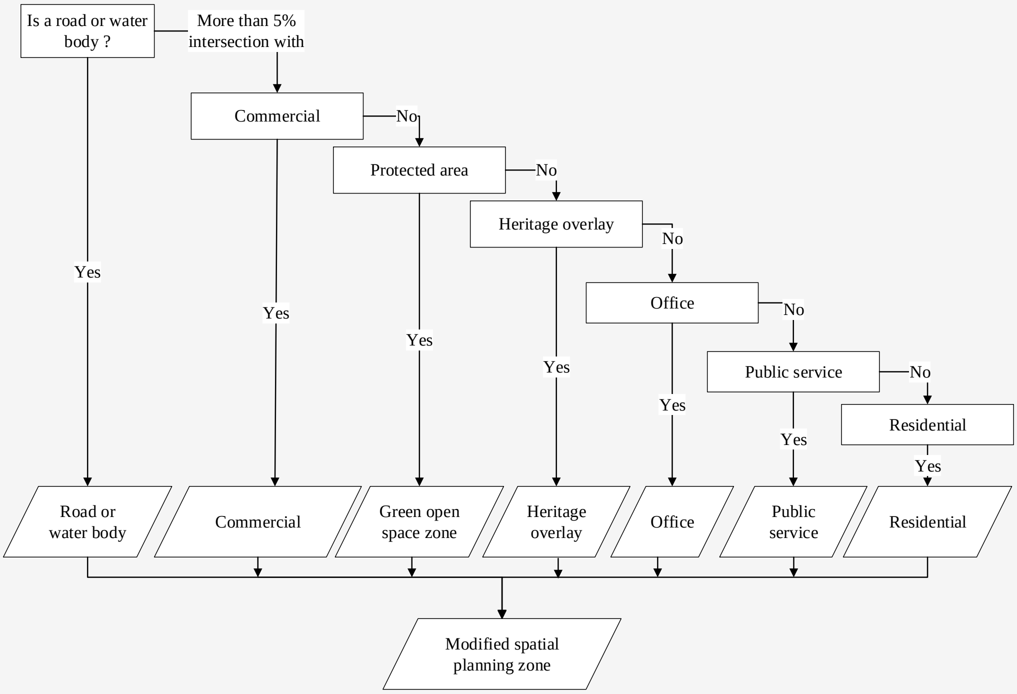


Figure 4: Logical scheme of spatial zone unification if cadastral land parcel has intersected with more than one zone

Unifying multiple spatial planning zone attributes on one cadastral land parcel should consider the existing use and the dominant zones clustering around the parcel. At this stage, the output was the original and modified zoning maps based on the land parcel. This quantification evaluated the impact of harmonising zoning maps and cadastral data.

2.2.3 Development of a proposed zoning map

The land parcel map was used as the base geometry to identify land utilisation. It was assisted by UAV photo interpretation and supplemented by field surveys. The types of land use were referred to in the RDTR of Yogyakarta, issued as the mayor's regulation number 118/2021. There are 16 types of land utilisation, namely green open space, residential, commercial, hospitality, services, tourism and recreation, industry, offices, mixed-use, non-green open space, educational facilities, transportation facilities, health facilities, religious facilities, social and cultural facilities, and other uses. From these 16 land use types, 237 sub-activities can be derived. The result of this stage is a land utilisation map based on land parcels.

2.2.4 Analysis of land use suitability of the harmonised map

The land use suitability assessment was conducted using a matrix of land use permission classification [39], the ITBX comparison matrix. The ITBX matrix is a land utilisation control regulation according to zoning regulation. The suitability of land utilisation is evaluated based on the land use designation described in the zoning regulations (zones and sub-zones) in the RDTR. The zones and subzones are divided into protected areas and developable areas. Each zone/subzone regulates activities that are permitted (I), limitedly permitted (T), conditionally permitted (B), conditionally and limitedly permitted (TB), and prohibited (X). The classification of land use suitability refers to this matrix, which is part of the zoning regulations in the RDTR regulations and can be seen in Table 2 [40]. The simplified ITBX matrix is shown in Table 3. The original ITBX matrix, which has 237 rows x 33 columns. The column represents spatial planning, the row represents land utilisation, and the cell shows the suitability regulation. Each land parcel was evaluated for suitability by comparing the land use designations against the two zoning maps before and after the harmonisation process. The area results of suitability analysis were compared quantitatively using chi-square testing. Further, the results were analysed to determine the impact of harmonisation on the suitability of land use in the study area.

Table 2: Land utilization suitability condition

Regulation	Symbol	Conditions
Permitted	I	If the utilisation is in accordance with the land use designation.
Limitedly permitted	T	If the utilisation is limited in time, intensity, and extent of use.
Conditionally permitted	B	If the utilisation requires certain permit documents.
Limitedly and conditionally permitted	TB	If the utilisation requires specific requirements and is limited.
Prohibited	X	If the utilisation is not by the land use designation, it can considerably impact the surrounding environment.

Table 3: Simplified ITBX matrix [40]

		Spatial planning								
		Protected Area	Green Open Space	Heritage overlay	Road	Residential	Commercial	Office	Public Facility	Transportation
Land utilization	Green open space	I	I	I	X	I	I	I	I	I
	Residential	X	X	TB	X	I	I	I	B	I
	Trade	X	X	B	X	TB	I	B	X	B
	Hotel	X	X	B	X	B	I	B	B	B
	Service	X	X	B	X	I	I	I	I	I
	Tourism and Recreation	X	TB	B	X	TB	I	B	I	I
	Industry	X	X	TB	X	B	I	I	I	I
	Office	X	X	B	X	I	I	I	I	I
	Mix land-use	X	X	B	X	I	I	I	B	B
	Non-green Open Space	X	I	B	X	I	I	I	I	I
	Education	X	X	TB	X	B	I	I	T	B
	Transportation	X	X	TB	X	X	I	I	I	I
	Health Facility	X	X	TB	X	I	I	I	B	B
	Religion	X	X	TB	X	B	I	I	I	I
	Social and culture	X	X	I	X	I	I	I	I	I
	Other	X	I	I	X	B	I	I	B	I

3. Results and Discussions

3.1 Geometric Inconsistencies between RDTR Zoning Map and Land Parcel

The geometric inconsistencies between the zoning map and the land parcel map hinder the realisation of the one-map policy in the land development aspect of modern LAS [41]. The harmonisation is carried out to align the boundaries between the zoning map and the land parcel map. The harmonised dataset will ensure each land parcel has a unique land use designation. The current situation indicates that many land parcels have two or three different land use designations. Ideally, road boundaries in the real world, the zoning map, and the cadastral maps have the exact representation and position boundaries [42]. However, the boundaries of these datasets are not always in the same locations. The road network map used as the base data for analysis was obtained from interpreting UAV photos. If the zoning map and cadastral map are overlayed on the road network from UAV, the alignment of the zoning map is better than that of the cadastral map. The zoning map has around 50% matched to the road network from UAV, while the cadastral map was less than that. These mismatches resulted from different scales and domains in these three datasets.

Dimensional harmony refers to the suitability of a boundary covering two or more objects. If the dimensions between the two datasets are aligned, they will match and cover each other according to their boundaries [43]. Based on the dimensional evaluation, the shape of the land parcel and the zoning map are similar to those of the same block. However, when examined in more detail, as shown in Figure 5, there are object that resemble the pattern but do not have the exact dimensions and shape. The boundary elements of these datasets are not aligned. Figure 5(a) is residential buildings represented in the cadastral map, Figure 5(b) is a boundary of the zoning map, and Figure 5(c) is a combination of the two data. It is evident that the representation of objects between the two datasets has different boundaries. The boundary of the land parcel map is more distinctive and matches the boundary of the physical entity represented in the orthophoto. In contrast, the representation zoning map boundary is less unique and does not follow the shape of the represented object. The possible causes of the differences are map scale, the modelling domain, and data sources to produce the datasets.

The differences in boundary geometry occur due to the use of different references and scales. It significantly impacts the topological relationship between the zoning and land parcel maps. The domain of the urban land parcel map is at 1:1,000 scale with the designation of land parcel registration. The error tolerance value is a maximum of 0.5 m. Meanwhile, the domain of the RDTR is at the scale of 1:5,000 with an error tolerance of 2.5 m [44] and [45]. Therefore, intrinsically, the object boundary between these datasets is different.

The inconsistency in this geometrical aspect impacts the area calculation between datasets. For Mantrijeron district, there are three calculated areas: 2,684,116 m^2 from the administrative map, 2,691,586 m^2 from the cadastral map, and 2,664,416 m^2 from the zoning map. The smallest area is based on the zoning map, 0.73% smaller than the cadastral map. This difference is a result of disharmony in the boundary of each dataset.

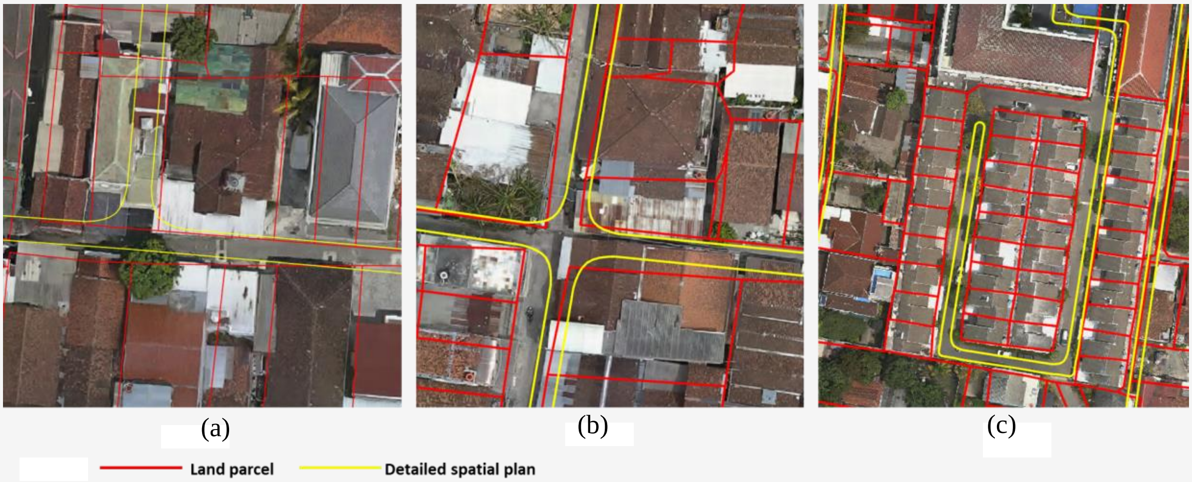


Figure 5: Differences in element shapes with orthophoto base map; (a) land parcel boundary; (b) detailed spatial plan zone boundary; (c) overlay of both

ISSN: 1686-6576 (Printed) | ISSN 2673-0014 (Online) | © Geoinformatics International

Table 4: Calculations for evaluation of area, land parcel area, and zoning map

Village	Number of land parcel	Land parcel with one sub-zone	Land parcel with two sub-zones	Land parcel with three sub-zones
Suryodiningratan	3,313	2,477	764	72
Gedongkiwo	3,394	2,470	835	89
Mantrijeron	2,774	2,082	612	80
Total	9,481	7,029	2,211	241

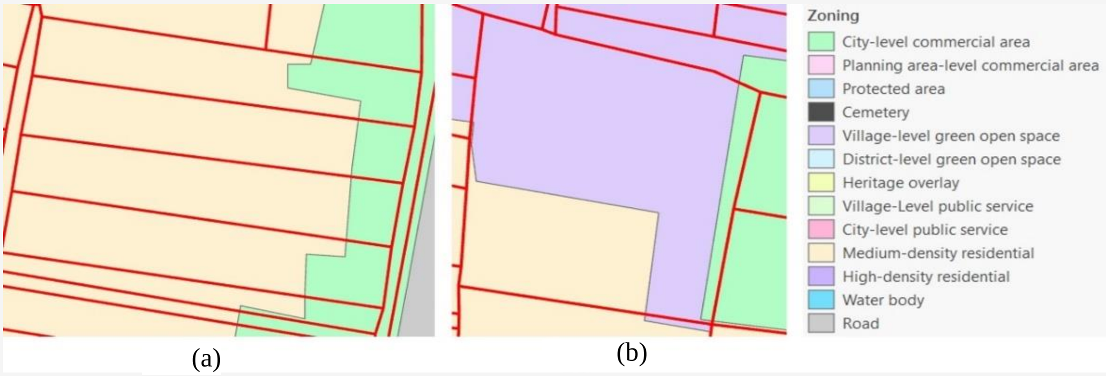


Figure 6: Examples of incompatibility between spatial plan data and land parcels; (a) example of one two-zone parcel; (b) example of one three-zone parcel

Different institutions/organisations in data production for the exact object representation have different geometries that impact area calculations. The differences in the area can also result from land parcel maps that have not been harmonised with the zoning map boundaries. Proportionality evaluation was conducted to check any land parcel with more than one sub-zone in the RDTR. This evaluation was done in each village, and the number of land parcels having more than one zone can be seen in Table 4. Based on the table, Gedongkiwo has the highest number of land parcels with more than one spatial zone. Meanwhile, Suryodiningratan has the lowest number of land parcels overlapping three spatial zones (72). Then, Mantrijeron has the lowest number of land parcels for one parcel with two spatial zones.

According to [46], to realise consistency, optimisation of the spatial plan, and effective resource allocation, each land parcel should ideally have only one sub-zone in the detailed spatial plan. The condition in Mantrijeron is not ideal, as approximately 26% of the land parcels intersect with two or three sub-zones. In the three villages of Mantrijeron District, the percentage of land parcels in optimal condition ranges from 72.8% to 75.1%. Figure 6 depicts the appearance of a land parcel intersected by more than one sub-zone. Figure 6(a) shows land parcels intersected by commercial and medium-density residential sub-zones. In Figure 6(b), the land parcel is intersected by three sub-zones: commercial, medium-density, and high-density. These conditions were adjusted using the method discussed in section 2.2.2 to obtain the ideal situation.

3.2 Harmonised zoning and cadastral maps

The harmonisation process is carried out by aligning the geometry elements of the land parcel map, including road network and water bodies, using UAV photos as the reference data. The zoning map is also adjusted to the land parcel map to make them ideal using a priority hierarchical approach. The result of the harmonisation process is a land parcel-based zoning map. The results and comparison of the previous zoning map with land parcel-based zoning is presented in Figure 7. Figure 7(a) shows the zone-based zoning map (initial zoning map), and Figure 7(b) is the cadastral land parcel-based zoning map. To better visualise the spatial cadastral-based zoning map, a modified zoning map was generated by dissolving the cadastral land parcel-based zoning map result (modified zoning map Figure 8). Following the harmonisation process, an area coverage analysis for all sub-zones can be conducted before and after. Table 5 presents the area comparison of each sub-zone. The table indicates that the road zone exhibits the highest percentage difference of 109.03%.

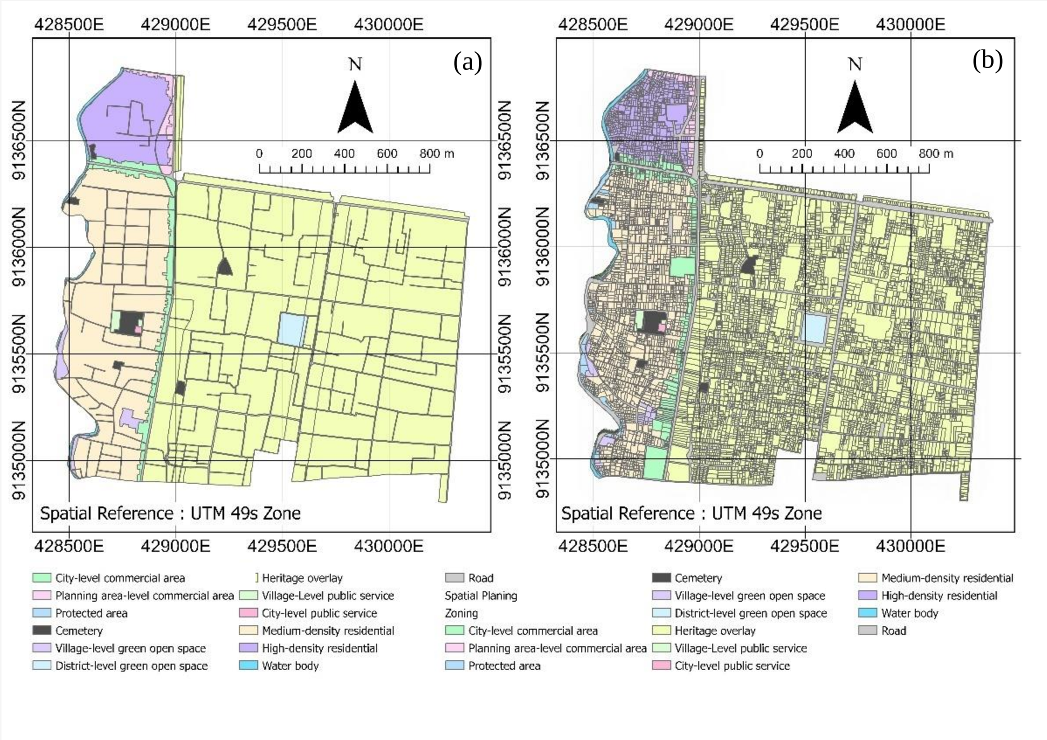


Figure 7: Spatial planning and land parcel harmonisation result; (a) initial zoning map; (b) land- parcel-based zoning

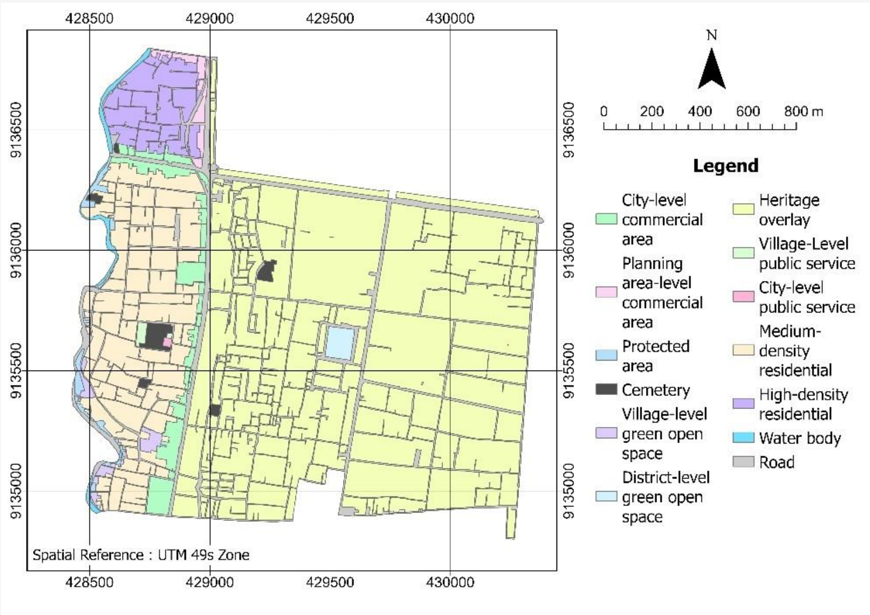


Figure 8: Final modified spatial planning map

The previous section elucidates a notable disparity in road geometry between the land parcel and the zoning map. Consequently, there exists a significant difference in area. The road network on the cadastral map is twice the size of the RDTR. The city-level trade and services represent the spatial zone with the minimum area difference, recorded at 0.068%. The mean difference across all spatial sub-zones is 19.00%. The area of each zone of the original and modified zoning map is significantly different.

Table 5: Comparison of zoning-based and parcel-based spatial planning areas

Spatial Planning Zone	Zoning-based (m²)	Parcel-based(m²)
Heritage overlay	1,626,118	1,668,999
Cemetery	20,598	21,716
City-level commercial	84,638	87,074
District-level commercial	16,542	18,260
Protected area	4,952	19,325
Medium-density residential	437,901	430,374
High-density residential	119,970	122,705
Village-level public service	3,918	4,050
City-level public service	1,153	1,154
District levels open space	13,755	14,115
Village-level open space	13,836	16,691
Waterbody	11,770	13,720
Road	159,768	333,960
Total	**2,514,925**	**2,692,425**

To utilise cadastral data capable of supporting all functions of LAS, the geometric aspect must be of good quality. The cadastral data from the study area is yet to meet this requirement. Only land parcels are well represented, while roads and water bodies need to be included in some parts. This situation results from the primary objective of cadastral mapping, that is registering and mapping land parcels. Water bodies and road infrastructures remained out of scope and were not appropriately represented. To fill this gap, the water body and roads were digitised using the most recent UAV photo with modifications according to aerial orthophoto. Some land parcels had been misplaced systematically from their positions over the aerial orthophoto. Therefore, a systematic positional adjustment was carried out to fit it better with the real world.

3.3 Land Utilisation Map

The land utilisation map for 2024 was produced using the land parcel map as the base data. It contains information on the types of land utilisation activities. The information was derived from field surveys supplemented by aerial photo interpretation. The land utilisation information is grouped based on the classification of activities in the zoning regulations. The land utilisation distribution is presented in Figure 9. Meanwhile, Figure 10 shows a bar chart of the area of each land utilisation activity. According to both, residential areas dominate study areas with 59.32% coverage. Apart from residential areas, green open space dominates land utilisation, which has an area proportion of 9.21%. The type of green open space that dominates the study area is the community garden, which is associated with the residential areas. The land utilisation activity with the smallest area is an industrial area, with an area proportion of 0.27%. The industrial area in the study area is not a large but a household-scale industry. Since the study area is part of an urban area and a heritage overlay, the dominating land utilisation is residential area and green open space. The industrial area has a small portion because the designation of the area study is not specifically as an industrial centre.

The process of identifying land utilisation reveals three categories: a single land parcel has a single use, multiple uses in one parcel, and multiple land parcels have a single use. Figure 11(a) illustrates a land parcel exhibiting multiple land utilisation, specifically designated for housing and health facilities, encompassing an area of 305 m². Figure 11(b) illustrates three land parcels, each demonstrating a land utilisation area of 3,522.40 m². Those multiple cadastral land parcels are designated for public gas stations. The existence of a single cadastral land parcel with multi-land utilisation is actual instances of the issues of using the cadastral land parcel for land utilisation identification. Land utilisation identification should ideally focus on a single object of utilisation [39]. A single object utilisation is typically represented by a building [47]. The condition of multi-parcel utilisation has no inconsistency in the land utilisation type. There is the potential for a single right base to encompass multiple building objects. Consequently, there is a lack of consistency in the land utilisation type on a single parcel. The findings of this research case study prove the problem of using cadastral land parcel as a single land utilization for base information.

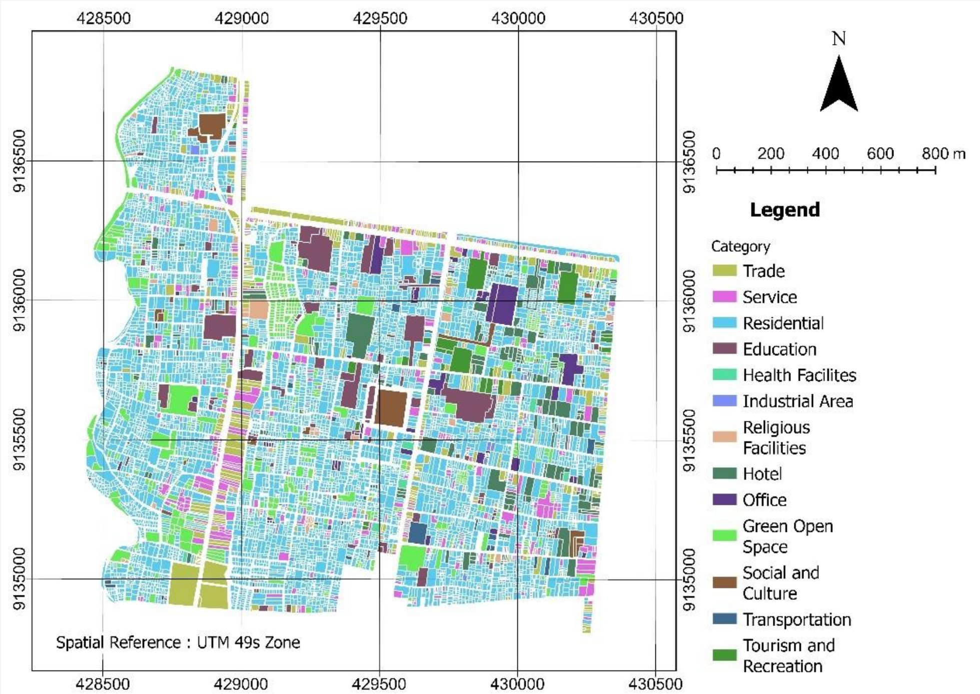


Figure 9: Parcel based land utilisation map of Mantrijeron District 2024

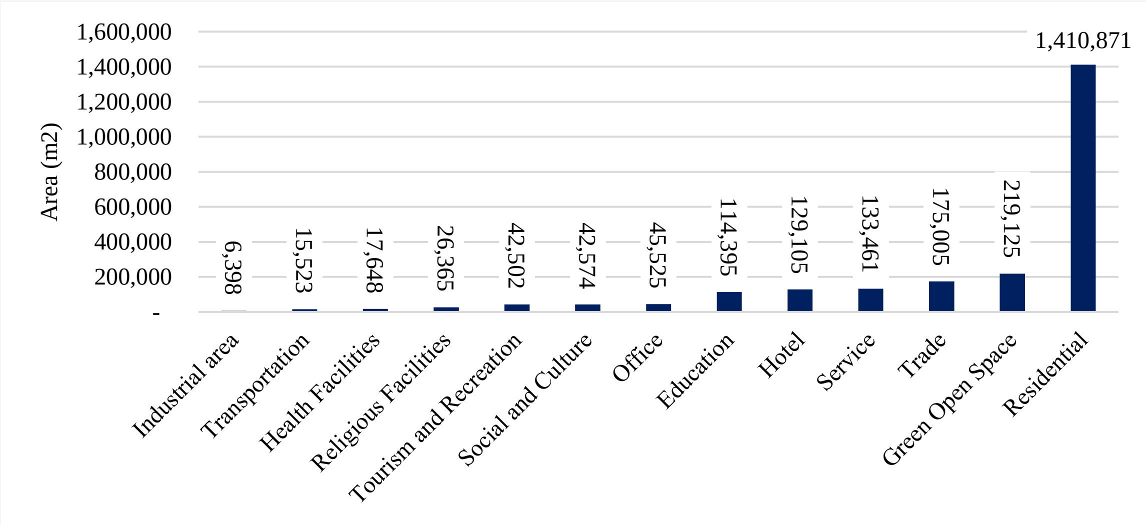
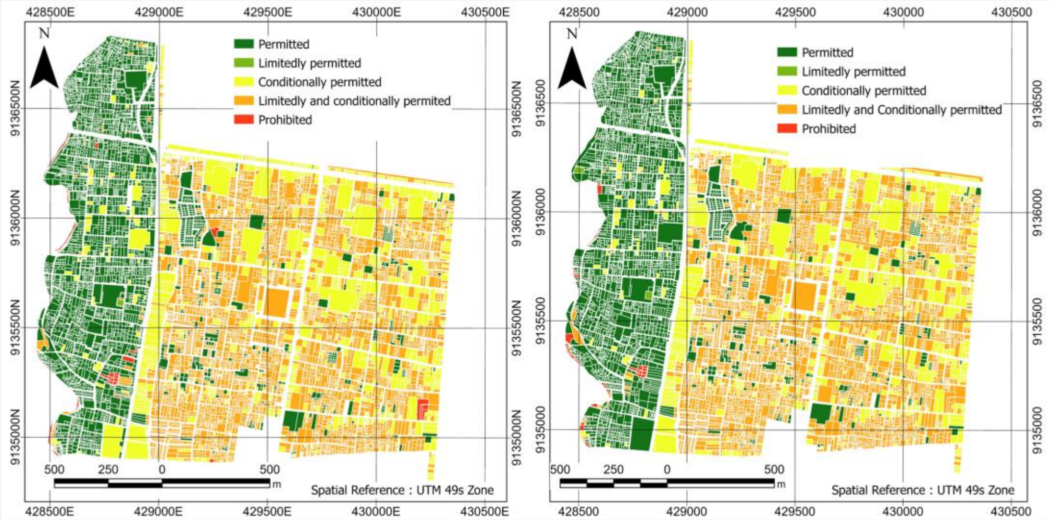


Figure 10: Area of each category of Mantrijeron District 2024 land utilisation

(a) (b)

Figure 11: Specific phenomena of spatial utilisation in cadastral land parcel-based evaluation; (a) example of one cadastral land parcel with multi-land utilisation; (b) one-land utilisation with multi-cadastral land parcel



(a) (b)

Figure 12: Map of land utilisation evaluation; (a) referenced using original zoning map; (b) referenced using modified original zoning map

3.4 Land Utilisation Evaluation

The assessment of land utilisation enhances accountability and trust within public and private institutions, particularly regarding investment activities [48]. This evaluation is essential in understanding how implementing spatial planning policies can control land use in a given area [49]. It evaluates the compatibility of land utilisations through the ITBX matrix, describing the conformance of land utilisations and the detailed spatial plan.

The 2024 land utilisation and land parcels maps generated the land utilisation suitability assessment referenced to the original and modified original zoning maps. The results of these evaluations are presented in Figure 12. Permitted suitability is dominated in Gedongkiwo Village, while the other two villages are dominated by conditionally and limited suitability. This is because Gedongkiwo Village has a varied spatial zoning plan, while the other two villages are relatively monotonous. In Suryodiningratan and Mantrijeron Villages, almost all areas are heritage overlay areas. Furthermore, most of Suryadiningratan and Mantrijeron Villages have land utilisation in the form of residential, which, when located in areas planned as heritage overlay, have limitedly and conditionally permitted regulations. Comparing visually between the evaluation results using the original map and the modified zoning map, there are slight differences of land utilization evaluation result, such as land parcels on the eastern side of the southern part of Gedongkiwo Village. This location contains a relatively large parcel, which is conditionally permitted when evaluated with the original zoning map. When assessed with the modified zoning, the designation is changed into permitted. The difference is that, in the evaluation using the original map, the zoning map intersects the cadastral land parcel so that one land parcel has more than one zoning, and the evaluation is determined based on the dominating area. Meanwhile, by implementing a hierarchical system on the modified zoning map, each land parcel has only one zoning, making it more reliable.

The area of each suitability class in the original zoning map and modified zoning map (parcel-based) evaluations are presented in Table 6. Both of evaluations techniques produce the highest area of limited and conditional suitability but have slightly different in area percentages. Using the modified zoning map, the resulting percentage area is 40.72%, while evaluated with original spatial planning (zoning map-based), it has a percentage area of 44,11%. The lowest percentage in both evaluation techniques was also limitedly suitable with a percentage area of 0.10% in both modified and original zoning map-based evaluation. There is a difference in total area between evaluation results using the original and modified zoning map. The reasons for this area are the different administrative boundaries used by the two data domains, as discussed in the previous section. The significance difference of the cadastral land parcel-based land utilisation evaluation across the original spatial planning zone was tested using chi-square, with a table value for $\chi^2_{0,05;df=6}$ of 14.067.

Table 6: Area of each suitabilitble class land utilisation evaluation referenced to original spatial zoning map and cadastral land parcel

Land Utilization Suitability	Land area; m^2 [%]	
	Zoning map based	**Cadastral land parcel based**
Permitted	704,145 [28.91%]	768,682 [30.58%]
Limited	2,495 [0.10%]	2,434 [0.10%]
Condiitional	462,326 [18.98%]	537,173 [21.37%]
Limited and Conditional	1,074,408 [44.11%]	1,023,584 [40.72%]
Unpermitted	20,712 [0.85%]	10,600 [0.42%]
Road	159,769 [6.56%]	159,769 [6.36%]
Water Body	11,771 [0.48%]	11,771 [0.47%]
Total	2,435,624	2,514,012

(a) (b)

Figure 13: Example of geometric harmonisation;
(a) accessibility aspect consideration; (b) rigidity aspect consideration

The area of rejection of the hypothesis in this test refers to equations $p - value < 0{,}05$ p or $|\chi^2_{hitung}| > \chi^2_{tabel}$. The statistical results indicate a $p - value$ of $2{,}2 \times 10^{-16}$ and a χ^2_{test} of 23.979. The null hypothesis is rejected because the $p - value$ is less than 0.05, and the calculated chi-square statistic exceeds the critical value. Consequently, there are notable differences between area-based and zone-based land utilisation evaluations. Statistical testing results indicate that harmonising spatial data into land parcel-based zoning maps has significant implications for evaluating land utilisation.

The disparity in each category of land utilisation evaluation is evident when comparing the original zoning maps and the parcel-based zoning maps. Ideallnt, each land parcel should be associated with a single spatial zone. Integrating a zoning map with a land parcel map may result in a single parcel having multiple zones. Unifying spatial planning zones for a multi-spatial planning zone in land parcels presents significant challenges. Suppose a parcel is situated in a trade-service and residential zone (refer to Figure 13(a), the appropriate zone to select is either commercial or residential. Two alternatives exist for determining the zone of a cadastral land parcel. The first option involves choosing the area of the dominant spatial zone, provided that no regulatory issues are present. Attention must be directed towards the area that interfaces with the access road to the land parcel. The second alternative posits that the principle of area dominance may be disregarded if the zone associated with the land parcel interacts with the access road despite not being the predominant area. If the land parcel has access to roadways and is in a commercial zone, it may be assigned for that purpose, despite the area not being dominant. Both accessibility and the rigidity of spatial planning regulations were examined. If a parcel intersects with green open space and settlements (refer to Figure 13(b), the designated zone on the parcel is classified as green open space. The present regulations prohibit using areas other than green open spaces. The issue of multiple zones within a single cadastral land parcel in urban areas is significant, requiring a more thorough examination of each parcel exhibiting multi-zonal spatial planning to achieve geometric harmonisation.

The presence of this phenomenon should be a primary concern for the government when harmonising the spatial planning map with the land parcel map. A collaborative approach is essential for harmonising syntax, structure, and semantics. Geometry harmonisation is a straightforward process from a technical perspective. However, attribute harmonisation presents substantial challenges in adapting to the specific conditions of each region.

The automatic attribute aggregation method has been extensively utilised in prior research, employing descriptive statistical techniques for continuous data and area aggregation for discrete data [50][51] and [52]. In the framework of this study, consideration of data quality, regulation, and community participation remains important. This process requires the evaluation of the priority and significance of specific objects, ensuring their harmonisation [53]. This harmonisation is a reference for developing RDTR zoning maps derived from cadastral land parcels, particularly in urban areas.

Land parcel-based spatial planning unification plays an important role in supporting LADM in the study area. In addition, several case studies have similar problems with the study area issues, where a single land parcel has more than one spatial planning. This issue is found in Lagos Megacity, Nigeria. The main challenge of the country's problem is the lack of understanding among institutions in terms of semantics, scope, and practice of spatial or physical planning [54]. Some countries implement a domain-specific design model with a hierarchical scheme of the smallest spatial planning units. The smallest spatial planning unit in Turkey uses land parcels. The LADM model was adopted to bridge the inconsistency between spatial planning data and cadastral land parcels. As a result, Turkey's spatial planning system has only one planning zone for each single land parcel [17]. The development of spatial planning models in China uses buildings as the smallest planning unit. The land parcel in the model is a planning block that makes it possible to integrate with the cadastral system. It can facilitate data exchange and improve the efficiency of land administration systems [55]. The unification of cadastral land parcel-based can increase the investment potential as it supports interoperability, which can ensure the accuracy and availability of spatial planning. The data serves as a reference in assigning restrictions and responsibilities to each land parcel. Lack of harmonisation of cadastral land parcels and spatial planning can lead to unequal opportunities among economic actors, resulting in inequality in economic development [56].

Several issues that potentially limit the successful implementation of harmonisation of cadastral land parcels and spatial planning areas are limited data access, data updating, incomplete data, and base maps that lack accuracy [57]. Limited data access by data-holders is the most significant challenge [58]. Data availability of some institutions is still limited, especially in Indonesia. In addition, data updates or temporal aspects will affect the quality of decision-making in spatial planning, given the dynamics of change in urban structure. Data completeness influences the reliability of the database in harmonising two sets of data. Before harmonising, ensuring that both data are complete according to real-world representation and the accompanying metadata is the the key to the successfull harmonisation. A common issue is the lack of completeness of cadastral land parcels [59], resulting in less reliable harmonisation results. The base map used as the harmonisation reference base should meet the accuracy of the map scale standard. Since spatial planning is implemented on a cadastral land parcel, and the cadastral land parcel has a scale of 1:5,000, the horizontal accuracy of the base map must be greater than 1.25m. A base map with incompatible accuracy will give unreliable results towards the expected output.

This study shows how successfully harmonising cadastral land parcels with spatial planning using UAV imagery and field surveys as databases can be executed. The quality of harmonisation results is influenced by the base map that is used. Very high-resolution UAV imagery (5 cm in this study) helps identify current land utilisation and improve the delineation between land parcels and real-world objects, which then become spatial planning base. The accuracy of UAV imagery affects the reliability of the results of harmonising land parcels with spatial planning. Hence, the representation of real-world objects by land parcels is more reliable. Therefore, UAV imagery acquisition techniques play an important role in producing optimal accuracy as the base map in the harmonisation process of this research. The domain of measurement techniques and the depiction of objects by spatial planning and cadastral land parcels is a significant challenge for the harmonisation process because of the resulting difference in accuracy. Ensuring the accuracy and reliability of spatial data is very important. Inaccurate data can reduce the quality of decision-making related to spatial utilisation and control.

4. Conclusions

This study examined how to harmonize spatial planning maps with cadastral land parcels, focusing on Mantrijeron Village in Yogyakarta City, Indonesia. Using UAV imagery as a base map, we addressed geometric inconsistencies between the two data sets. The result of this harmonization is a parcel-based spatial planning map. A significant issue identified was that over 25% of cadastral land parcels in the study area intersect with multiple spatial planning zones. This means a single cadastral land parcel can be subject to multiple spatial planning regulations.

The study proposed a hierarchical system to unify spatial planning to address this complexity. This system considers accessibility, correlated with main roads, and the rigidity of spatial planning zone classifications. When comparing the original spatial planning map to the unification result of parcel-based spatial planning, the average area difference of each zoning class is 19%. As the smallest unit of spatial planning, the land parcel has a higher reliability than the original spatial planning map to support the implementation of sustainable LAS.

Parcel-based spatial planning was used as a reference for spatial utilisation evaluation. The evaluation results indicate that the study area is dominated by limited and conditionally suitability, with an area of 1,023,584 m^2 (40.72%). This situation was mainly attributed to the dominance of the heritage overlay planning zone in the region. Furthermore, the land utilisation in the study area is dominated by residential, accounting for 59.32% of the total coverage. As a results, the suitability of land utilisation according to the local mayor's regulations is limited and conditional. The area of spatial utilisation evaluation results using parcel-based spatial planning significantly differs from original spatial planning in a 95% confidence level of statistics. The significant difference is due to the different administrative boundary domains used by original spatial planning and cadastral map.

The approaches proposed in this study offer recommendations for harmonising the spatial planning map and cadastral map. Each land parcel only has one land use designation. However, it is essential to consider institutional arrangements further to ensure that spatial data sharing can enhance this process, as well as the analysis of existing conditions, land valuation, and environmental capacity. The more comprehensive the factors taken into account, the more accurate and feasible the data harmonization will be.

Acknowledgement

The authors would like to thank the Directorate of Research Universitas Gadjah Mada (UGM), grant number 6529/UN1.P1/PT.01.03/2024, for funding this research. The authors would also like to thank the Land and Spatial Planning Office of Yogyakarta City, the Yogyakarta City Land Office; and the Public Works, Housing, and Settlement Area Office of Yogyakarta City.

References

[1] Enemark, S., (2004). Building Land Information Policies. *Proceedings of UN, FIG, PC IDEA Inter-regional Special Forum on The Building of Land Information Policies in the Americas,Aguascalientes, Mexico*. Oct. 27, 2004. International Federation of Surveyors (FIG).

[2] Ting, L., (2002). *Principles for an Integrated Land Administration System to Support Sustainable Development*. Doctoral Thesis. University of Merbourne.

[3] Diyono, D. and Subaryono, S., (2014). Harmonisasi Data Spasial untuk Mendukung Proses Pengendalian Alih Fungsi Lahan [Spatial Data Harmonisation Supporting the Land Use Change Control Process]. *Proceedings of Towards Sustainable Engineering*, *Annual Engineering Seminar 2014*, *Yogyakarta*. Feb. 12, 2014. Faculty of Engineering, Universitas Gadjah Mada.

[4] Enemark, S. and Sevatdal, H., (1999). Cadastres, Land Information Systems and Planning-Is Decentralisation a Significant Key to Sustainable Development. *Proceedings of UN-FIG Conference on Land Tenure and Cadastral Infrastructures for Sustainable Development*, *Melbourne Australia*. Oct. 27, 1999. International Federation of Surveyors. 1-15. https://www.fig.net/resources/proceedings/1999/figun/sessions/session2/enemark.pdf.

[5] Okembo, C., Morales, J., Lemmen, C., Zevenbergen, J. and Kuria, D., (2024). A Land Administration Data Exchange and Interoperability Framework for Kenya and Its Significance to the Sustainable Development Goals. *Land*, Vol. 13(4). https://doi.org/10.3390/land13040435.

[6] Saeidian, B., Rajabifard, A., Atazadeh, B. and Kalantari, M., (2023). Data Lifecycle of Underground Land Administration: A Systematic Literature Review. *Survey Review*, Vol. 55(392), 396-415. https://doi.org/10.1080/00396265.2022.2119744.

[7] Morales, J., Lemmen, C., de By, R. A., Ortiz Dávila, A. E. and Molendijk, M., (2021). Designing All-Inclusive Land Administration Systems: A Case Study from Colombia. *Land Use Policy*, Vol. 109. https://doi.org/10.1016/j.landusepol.2021.105617.

[8] Njogu, S., Antonio, D., Gitau, J., Mwesigye, S. and Ram, R., (2021). Flexible Land Information System Championing Reform Towards Formal Cadaster in Developing Countries. *Proceedings of Smart Surveyors for Land and Water Management–Challenges in a New Reality, Netherland*. Jun. 25, 2021. International Federation of Surveyors (FIG). https://www.fig.net/resources/proceedings/fig_proceedings/fig2021/papers/ts07.5/TS07.5_njogu_antonio_et_al_11088_abs.pdf.

[9] Bennett, R., Wallace, J. and Williamson, I., (2005). Integrated Land Administration in Australia: The Need to Align ICT Strategies and Operations. *Proceedings of Proceedings of Spatial Sciences Institute Conference, Melbourne Australia*. Sep. 2005. Spatial Sciences Institute.

[10] Rajabifard, A., (2002). *Diffusion of Regional Spatial Data Infrastructures: With Particular Reference to Asia and the Pacific*. Doctoral Thesis. Geomatics. University of Melbourne.

[11] Owusu Ansah, R., (2022). Assessment of Land Information System for Land Administration: A Case Study of Ghana. Master Thesis. Faculty of Geo-Information Science and Earth Observation. University of Twente. [Online]. Available: https://essay.utwente.nl/91434/1/Owusu%20Ansah_MSc_ITC.pdf. [Accessed: Nov. 30, 2024].

[12] Kurwakumire, E., Coetzee, S. and Schmitz, P., (2022). Towards Monitoring and Managing the Production of Cadastral Information in Land Information Infrastructures Using Supply Chain Mapping and the Supply Chain Operations Reference (SCOR) Model. *South African Journal of Geomatics*, Vol. 9(2), 163-178. https://doi.org/10.4314/sajg.v9i2.12.

[13] Faxon, H. O., Goldstein, J. E., Fisher, M. R. and Hunt, G., (2022). Territorializing Spatial Data: Controlling Land through One Map Projects in Indonesia and Myanmar. *Political Geography*, Vol. 98. https://doi.org/10.1016/j.polgeo.2022.102651.

[14] Lemmen, C., van Oosterom, P. and Bennett, R., (2015). The Land Administration Domain Model. *Land Use Policy*, Vol. 49, 535-545. https://doi.org/10.1016/j.landusepol.2015.01.014.

[15] Palengkahu, M. R., (2023). One Map Policy: Digital Administration Methods as an Effort to Solve Land Overlaps in Indonesia. *Journal of Social Sciences and Cultural Study*, Vol. 1(1), 01-08. https://doi.org/10.61857/jsscs.v1i1.32.

[16] Chehrehbargh, F. J., Rajabifard, A., Atazadeh, B., Steudler, D., and Nugraha, B. W., (2024). Towards Sustainable Land Governance: Extending the LADM to Support Global Initiatives Parameters-A Case Study in Indonesia. *Proceedings of 12th International FIG Land Administration Domain Model & 3D Land Administration Workshop, Kuching, Malaysia*. Sep. 26, 2024. International Federation of Surveyors (FIG).

[17] Phonphan, W., Arunplod, C., Wongsongja, N., Utarasakul, T., Niemmanee, T., Kayee, P., Daraneesrisuk, J., and Thongdara, R. (2024). Evaluating Spatiotemporal Dynamics: A Comparative Study of Predictive Efficacy in Land Use Land Cover Change Models-Markov Chain, CA-ANN, and PLUS. *International Journal of Geoinformatics*, Vol. 20(6), 13–25. https://doi.org/10.52939/ijg.v20i6.3329.

[18] Bharathy, P., Suthakar, K., Wijeyamohan, S., and Surendran, S. (2024). Geospatial Analysis of Land Use/ Land Cover Changes in the Northern Province, Sri Lanka. *International Journal of Geoinformatics*, Vol. 20(5), 1–12. https://doi.org/10.52939/ijg.v20i5.3223.

[19] Thammaboribal, P., and TRIPATHI, N. (2024). Predicting Land Use and Land Cover Changes in Pathumthani, Thailand: A Comprehensive Analysis from 2013 to 2023 Using Landsat Satellite Imagery and CA-ANN Algorithm, with Projections for 2028 and 2038. *International Journal of Geoinformatics*, Vol. 20(5), 13–27. https://doi.org/10.52939/ijg.v20i5. 3225.

[20] Govedarica, M., Radulović, A. and Sladić, D., (2021). Designing and Implementing a LADM-Based Cadastral Information System in Serbia, Montenegro and Republic of Srpska. *Land Use Policy*, Vol. 109, 105732. https://doi.org/10.1016/j.landusepol.2021.105732.

[21] Guler, D., (2023). Implementation of 3D Spatial Planning through the Integration of the Standards. *Transactions in GIS*, Vol. 27(8), 2252-2277. https://doi.org/10.1111/tgis.13122.

[22] Fichtinger, A., Rix, J., Schäffler, U., Michi, I., Gone, M. and Reitz, T., (2011). Data Harmonisation Put into Practice by the HUMBOLDT Project. *International Journal of Spatial Data Infrastructures Research*, Vol. 6, 234–260. https://doi.org/10.2902/1725-0463.2011.06.art11.

[23] Kopsachilis, V. and Vaitis, M., (2021). GeoLOD: A Spatial Linked Data Catalog and Recommender. *Big Data and Cognitive Computing*, Vol. 5(2). https://doi.org/10.3390/bdcc5020017.

[24] Athanasiou, A., (2020). Data Structuring & Interoperability Options for Optimising 3D City Modelling. National Technical University of Athens. http://dx.doi.org/10.26240/heal.ntua.19210.

[25] Chojka, A., (2020). Semantic and Syntactic Interoperability Issues in the Context of SDI. *Geomatics and Environmental Engineering*, Vol. 14(3), 5-20. https://doi.org/10.7494/geom.2020.14.3.5.

[26] Kalantari, M., Syahrudin, S., Rajabifard, A. and Hubbard, H., (2021). Synchronising Spatial Metadata Records and Interfaces to Improve the Usability of Metadata Systems. *ISPRS International Journal of Geo-Information*, Vol. 10(6). https://doi.org/10.3390/ijgi10060393.

[27] Yabe, R., (2023). Multi-Platform Data Search and Access Method to Compose Digital Twins Using Metadata. *Journal of Architectural Informatics Society*, Vol. 0(0), 1-26.

[28] Zulkifli, A., Abbas, M., Hashim, N., Mustafar, M., Sulaiman, S., Razak, N., Yusop, M., and Nordin, S. (2023). Implementation of Stochastic Modelling in Enhanced Cadastral Databased for Multi-Classes Datasets. *International Journal of Geoinformatics*, Vol. 19(5), 43–53. https://doi.org/10.52939/ijg.v19i5.2657.

[29] Brisaboa, N. R., Luaces, M. R., Andrea Rodríguez, M. and Seco, D., (2014). An Inconsistency Measure of Spatial Data Sets with Respect to Topological Constraints. *International Journal of Geographical Information Science*, Vol. 28(1), 56-82. https://doi.org/10.1080/13658816.2013.811243

[30] Roić, M., Križanović, J. and Pivac, D., (2021). An Approach to Resolve Inconsistencies of Data in the Cadastre. *Land*, Vol. 10(1). https://doi.org/10.3390/land10010070.

[31] Fetai, B., Tekavec, J., Fras, M. K. and Lisec, A., (2022). Inconsistencies in Cadastral Boundary Data Digitisation and Maintenance. *Land*, Vol. 11(12). https://doi.org/10.3390/land11122318.

[32] Arunplod, C., Phonphan, W., Wongsongja, N., Utarasakul, T., Niemmanee, T., Daraneesrisuk, J., and Thongdara, R. (2023). Spatial Dynamics Evolution of Land use for the Study of the Local Traditional Living Changes. *International Journal of Geoinformatics*, Vol. 19(4), 37–49. https://doi.org/10.52939/ijg.v19i4.2635

[33] Chen, M., Van Oosterom, P., Kalogianni, E., Dijkstra, P. and Lemmen, C., (2024). Bridging Sustainable Development Goals and Land Administration: The Role of the ISO 19152 Land Administration Domain Model in SDG Indicator Formalization. *Land*, Vol. 13(4). https://doi.org/10.3390/land13040491.

[34] Gedrange, C., Neubert, M. and Röhnert, S., (2011). Cross-Border Harmonisation of Spatial Base Data between Germany and the Czech Republic. *International Journal of Spatial Data Infrastructures Research*, Vol. 6, 53–72. https://doi.org/10.2902/1725-0463.2011.06.art3.

[35] Strzelecki, M., Iwaniak, A., Łukowicz, J. and Kaczmarek, I., (2013). Supporting Spatial Data Harmonization Process with the Use of Ontologies and Semantic Web Technologies. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, Vol. xl-7/w2 (7W2); 231–236. https://doi.org/10.5194/isprsarchives-XL-7-W2-231-2013.

[36] Chen, Y., Sabri, S., Rajabifard, A. and Agunbiade, M. E., (2018). An Ontology-Based Spatial Data Harmonisation for Urban Analytics. *Computers, Environment and Urban Systems*, Vol. 72, 177-190. https://doi.org/10.1016/j.compenvurbsys.2018.06.009.

[37] Jovicic, L., (2018). Spatial Data Harmonisation in Regional Context in Accordance with INSPIRE Implementing Rules. Doctoral Thesis. Physical Geography and Ecosystem Science. Lund University. [Online]. Available: https://lup.lub.lu.se/luur/download?func=downloadFile&recordOId=8939348&fileOId=8939350. [Accessed: Nov. 30, 2024].

[38] Nirandjan, S., Koks, E. E., Ward, P. J. and Aerts, J. C. J. H., (2022). A Spatially-Explicit Harmonized Global Dataset of Critical Infrastructure. *Scientific Data*, Vol. 9 (1), 1–13. https://doi.org/10.1038/s41597-022-01218-4.

[39] Tiarasari, R. and Kartidjo, W., (2021). Assessment of Pedestrian Walkability in the Urban Village with Urban Network Analysis. *IOP Conference Series: Earth and Environmental Science*, Vol. 738(1). https://doi.org/10.1088/1755-1315/738/1/012065.

[40] Yogyakarta Mayor, (2020). Yogyakarta Mayor Regulation about Detailed Spatial Plan of Yogyakarta City 2021-2041, 2020, *Indonesia*: No. 118 of 2021.

[41] Mika, M., (2020). Modernisation of the Cadastre in Poland as a Tool to Improve the Land Management and Administration Process. *Survey Review*, Vol. 52(372), 224–234. https://doi.org/10.1080/00396265.2019.1610211.

[42] Martono, D. B., Aditya, T., Subaryono, S. and Nugroho, P., (2021). The Legal Element of Fixing the Boundary for Indonesian Complete Cadastre. *Land*, Vol. 10(1). https://doi.org/10.3390/land10010049.

ISSN: 1686-6576 (Printed) | ISSN 2673-0014 (Online) | © Geoinformatics International

[43] Zhang, Z., Paulsson, J., Gong, J. and Huan, J., (2020). Legal Framework of Urban Underground Space in China. *Sustainability*, Vol. 12(20). https://doi.org/10.3390/su12208297.

[44] Pribadi, C. B., Hariyanto, T. and Puspita, A. I., (2018). Pembuatan Peta Dasar Skala 1:5000 Menggunakan Citra Satelit Resolusi Tinggi (Csrt) Pleiades 1-a Sebagai Acuan Pembuatan Peta Rdtr Pada Bagian Wilayah Perkotaan (Bwp) Lumajang, Kabupaten Lumajang [Development of a 1:5000 Scale Base Map Using Pleiades 1-a H]. *Jurnal Geoid*, Vol. 12(2), 153–157.

[45] Budi Santoso, E., Iswi, A. and Yanuasmara, I., (2024). *Planning Innovation in the Preparation of the Detailed Spatial Plan*. Aldieri, L., Ed., IntechOpen. https://doi.org/10.5772/intechopen.111838.

[46] Diyono and Sutanta, H., (2019). Peta Bidang Tanah Dalam Penyusunan Rencana Detail Tata Ruang [Land Parcel Map in the Preparation of Detailed Spatial Plan]. *Proceedings of Forum Ilmiah Tahunan - Ikatan Surveyor Indonesia*,2019. Ikatan Surveyor Indonesia.

[47] Dong, X., Xu, Y., Huang, L., Liu, Z., Xu, Y., Zhang, K., Hu, Z. and Wu, G., (2020). Exploring Impact of Spatial Unit on Urban Land Use Mapping with Multisource Data. *Remote Sensing*, Vol. 12(21). https://doi.org/10.3390/rs12213597.

[48] Lunt, N., Davidson, C. and McKegg, K., (2003). *Evaluating Policy and Practice: A New Zealand Reader*. Auckland, New Zealand. Pearson Education.

[49] Bulti, D. T. and Sori, N. D., (2017). Evaluating Land-Use Plan Using Conformance-Based Approach in Adama City, Ethiopia. *Spatial Information Research*, Vol. 25(4), 605-613. https://doi.org/10.1007/s41324-017-0125-3.

[50] Maldaner, L. F., Molin, J. P., Canata, T. F., Maldaner, L. F., Molin, J. P. and Canata, T. F., (2016). Processing Yield Data from Two or More Combines. *Proceedings of International Conference on Precision Agriculture, Missouri, USA*. Aug. 04, 2016. The International Society of Precision Agriculture. [Online]. Available: https://www.agriculturadeprecisao.org.br/wp-content/uploads/2019/11/cgr-2016_09.pdf.

[51] Sams, B., Litchfield, C., Sanchez, L. and Dokoozlian, N., (2017). Two Methods for Processing Yield Maps from Multiple Sensors in Large Vineyards in California. *Proceedings of Advances in Animal Biosciences*, Jul. 20, 2017. Cambridge University Press. https://doi.org/10.1017/S2040470017000516.

[52] Baume, O., Skøien, J., Carré, F., Heuvelink, G. and Pebesma, E., (2009). Data Harmonization of Environmental Variables: From Simple to General Solutions. *Proceedings of Towards eEnvironment. Opportunities of SEIS and SISE: Integrating Environmental Knowledge in Europe*, *Brno, Czec Republic*. Jan. 2009. Masaryk University.

[53] Mohammadi, H., Rajabifard, A. and Williamson, I. P., (2010). Development of an Interoperable Tool to Facilitate Spatial Data Integration in the Context of SDI. *International Journal of Geographical Information Science*, Vol. 24(4), 487–505. https://doi.org/10.1080/13658810902881903.

[54] Agunbiade, M., (2023). Spatial Planning and Land Administration Issues in the Lagos Megacity. *Urban and Regional Planning Review*, Vol. 9 (1), 1–9.

[55] Rahul, ND Kaur, R. (2024). Peri-urban Delineation and Urban Expansion Quantification from 2001 to 2021 of Hisar City, India, using Geospatial Techniques. *International Journal of Geoinformatics*, Vol. 20(4), 86–99. https://doi.org/10.52939/ijg.v20i4.3155.

[56] Indrajit, A., van Loenen, B., Suprajaka, Jaya, V. E., Ploeger, H., Lemmen, C. and van Oosterom, P., (2021). Implementation of the Spatial Plan Information Package for Improving Ease of Doing Business in Indonesian Cities. *Land Use Policy*, Vol. 105. https://doi.org/10.1016/j.landusepol.2021.105338.

[57] Anggara, E. D., Aditya, T. and Sutanta, H., (2025). PGIS for Tiered Participatory Development Planning. *International Review for Spatial Planning and Sustainable Development*, Vol. 13(1), 136–154. https://doi.org/10.14246/irspsd.13.1_136.

[58] Budi, S. and Sutanta, H., (2023). Worldwide Status of Geoportal and Geospatial Data Completeness at National Geoportals. *Proceedings of IOP Conference Series: Earth and Environmental Science*,2023. IOP Publishing. https://doi.org/10.1088/1755-1315/1276/1/012071.

[59] Mustofa, F., Aditya, T. and Sutanta, H., (2018). Evaluation of Participatory Mapping to Develop Parcel-Based Maps for Village-Based Land Registration Purpose. *International Journal of Geoinformatics*, Vol. 14(2), 45–55. https://journals.sfu.ca/ijg/index.php/journal/article/view/1134.