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Bridging Land Tenure Security and Sustainable Development: The Case of Semarang's Land Registration System

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ABSTRACT

Land registration is a fundamental foundation for land tenure security that supports the achievement of the Sustainable Development Goals (SDGs). However, the Complete Systematic Land Registration (CSLR) program in Indonesia faces a serious challenge: overlapping new certificates with old certificates, categorized as Cluster 4. This study aims to analyze the characteristics of Cluster 4 land plots, identify obstacles to resolving overlapping certificates, and formulate strategies to improve land data quality in Semarang City. Using a qualitative case study approach, data were collected through Focus Group Discussions (FGD) with 10 participants from the Semarang City Land Office, field observations in Gajah Mungkur sub-district, and secondary document analysis. Data analysis employed the fishbone (Ishikawa) diagram to identify root causes of problems. The results show that 62.3% of Cluster 4 land plots originated from the first period of land registration (1960–1997), with a significant decline in subsequent periods, indicating improvement in the land registration system over time. Technical constraints include inadequate data inventory, difficulties with field surveys (rights holders not found, measurement refusal), and overlaps during mapping. Non-technical constraints include limited human resources (local officials' ignorance and low public awareness), work accumulation, and budget limitations. This study formulates four integrated strategies: (1) periodic land data updates according to toponymy; (2) intensive socialization of land registration policies to the public; (3) collaboration with local governments through regional budget grant schemes; and (4) optimization of survey and mapping processes using appropriate technologies. These strategies are designed to address institutional weaknesses, build community norms and understanding of land registration, and support the achievement of the SDGs. The innovative collaboration scheme with local governments, funded through regional budgets, has proven effective in accelerating Cluster 4 resolution and can be replicated in other areas facing similar challenges.

1. INTRODUCTION

Land tenure security has emerged as an important concern across various development domains, including conservation, climate adaptation, food security, gender equality, and public health, due to its fundamental role in achieving sustainable development [1, 2]. At its core, tenure security reflects the creation of legal certainty through a bundle of recognized rights, including access, management, and legal processes with compensation [3]. When these rights are clearly defined and legally protected, landowners can safely use, benefit from, and maintain their land resources, enabling long-term investment and sustainable land management [4].

Legal certainty as the main goal in land registration has three important dimensions: (1) certainty of the status of registered land rights; (2) the certainty of the right holder (subject); and (3) the certainty of the land object, including the location, boundaries, and size of the land. Land registration operationalizes these dimensions by issuing certificates to rights holders, thereby providing legal protection for land ownership and use [5]. This certainty is fundamental not only for increase property security and prevent land conflicts that can hinder development, but also to enable the government to plan spatial development more efficiently and manage the area more effectively [6].

The importance of land ownership for sustainable development is recognized in the Sustainable Development Goals (SDGs). Land tenure security contributes to multiple SDGs: supporting poverty alleviation (SDG 1) by increasing asset value [7] and credit access [8], improving food security

(SDG 2) through agricultural investment [9], advancing gender equality (SDG 5) via equal land rights for women [10, 11], enhancing sustainable cities (SDG 11) by aiding spatial planning and slum prevention [12], promoting life on land (SDG 15) through reduced deforestation and sustainability [13], and strengthening institutions (SDG 16) by enabling transparent dispute resolution [14, 15]. The relationship between land tenure and sustainable development has evolved, focusing on poverty and hunger in the 1990s, economic growth in the 2000s, and climate change mitigation in the 2010s [16].

Realizing the importance of land registration for sustainable development, the Indonesian government launched the Complete Systematic Land Registration (CSLR) program in 2017. This program aims to accelerate land registration nationwide through a village-based, systematic approach. The main innovation of CSLRs is the digitization of land tenure data, transitioning from traditional paper-based systems prone to disputes to a digital era aligned with global standards [17]. The CSLR program generates four categories of data output: Cluster 1 (C1), Cluster 2, Cluster 3, and Cluster 4 [18]. Of the four CSLR product clusters, only Cluster 1 has the final product in the form of a land rights certificate with accurate spatial and textual information. C2 and C3 have only reached the stage of issuing land maps, but have not yet been equipped with juridical data. C4 – the focus of this research – refers to a plot of land whose objects and subjects have been certified (legally registered) but have not been in accordance with the field conditions and/or there have been changes in physical data. In other words, although C4 is legally recognized, its geospatial information has not been properly integrated into the land administration system. This condition leads to inaccurate spatial data, low data quality, and a discrepancy between digital data and field conditions.

A key issue in Cluster 4 is the overlap between CLSR certificates and old certificates. Overlapping rights lead to land conflict cases that Badan Pertanahan Nasional (BPN) has lost in court, accounting for 30.65% of such cases. These cases show failure in both physical and legal registration. Overlaps occur because old certificates were not spatially mapped, so new ones are issued on top but not mapped [19].

The consequences of these overlapping land certificates not only result in land disputes but also erode institutional credibility, and hinder the achievement of the SDGs. Therefore, improving the quality and geospatial integration of land registration data is not only an administrative refinement but also a structural intervention to restore tenure security and strengthen sustainable land governance.

Land registration plays a key role in ensuring tenure security that supports the achievement of the SDGs; however, overlapping land certificates indicate systemic weaknesses that undermine legal certainty; therefore, fishbone analysis is used in this study to identify the root causes of these overlaps.

2. METHODS

This study uses a qualitative case study to examine overlapping land certificates in Semarang, Indonesia. The method allows in-depth, contextual analysis of complex, real-world issues [20]. The qualitative approach reveals technical and non-technical land registration constraints, including human behavior and unique local factors, which quantitative methods do not capture [21].

The research location is determined using purposive sampling, in which samples are selected based on criteria relevant to the research objectives. The research was conducted in Central Java Province, with a large number of Cluster 4 drawn from data on the http://statistik.atrbpn.go.id applications. From this province, Semarang City was chosen as the study location because 1) Semarang City has the highest number of target Cluster 4 in Central Java Province, and 2) Semarang City represents urban areas with significant development pressures, making it an important object to understand land registration conditions in the context of sustainable urban development. The selection of one city with the most severe Cluster 4 problems follows the logic of critical case sampling, where findings can provide rich insights – with appropriate contextual adjustments – to areas with less severe problems [22].

The study uses triangulation to ensure the consistency and validity of the findings [23] through the following primary and secondary data sources.

1) Focus Group Discussion (FGD)

Two FGDs were conducted at the Semarang Land Office on June 14 and June 30, 2023. The first meeting identified obstacles in solving Cluster 4 problems and discussed solutions. The second meeting confirmed these findings. Ten participants attended, including the Head of the Semarang City Land Office (1), the Measurement and Mapping Section (3), the Land Rights Determination Section (3), and the Administrative Division (3). Each FGD lasted 120 minutes.

The FGD discussion guidelines are as follows.

a. What are the main obstacles in solving Cluster 4 problems?

b. How is the process of identifying overlapping certificates performed?

c. What strategies have been put in place to address the problem?

d. What resources and support are needed to accelerate the program?

e. How does the Cluster 4 issue affect landowners and development?

Documentation of FGD activities includes audio recordings to be transcribed verbatim, written notes, and photos.

2) Field observations were conducted to verify the physical condition of the cluster 4 land plot and to observe the survey and mapping process firsthand. The observation was carried out in Gajah Mungkur sub-district, Semarang City, on June 15, 2023. The researcher accompanied the survey team from the Land Office during the boundary measurement and verification. The observation checklist includes: the condition of the boundary marker, the presence of the landowner, the availability of documents, the technical obstacles encountered, and the community's response. Documentation of activities in the form of field notes and photos.

3) Secondary data is collected from various sources to complement and validate primary data in the form of laws and regulations, institutional annual reports, Geo-KKP databases, BPN (statistik.atrbpn.go.id) statistical data, land registration maps, previous studies (journals, reports on CSLR), as well as extraction from data on the computerized Land Office.

The main analytical tool used in this study is the fishbone diagram, also known as the cause-and-effect diagram or Ishikawa diagram, introduced by Ishikawa [24]. In this study,

fishbone diagrams are used to map the relationship between the impact (low achievement of the Cluster 4 certificate upgrade to Cluster 1) and the various causes that affect this process. The diagram's structure helps researchers think systematically, enabling them to identify the root cause. The initial fishbone diagram was presented to the FGD participants in a follow-up session as part of the validation process for the findings. Participants confirmed the diagram's results as the identified cause, thereby making the fishbone analysis reliable and valid. Additional quantitative descriptive analysis was carried out to determine the distribution of Cluster 4 land plots by the period of certificate issuance.

3. RESULTS AND DISCUSSIONS

3.1 Characteristics of Cluster 4 land plots

One of the most important goals of CSLR is to improve the quality of land data, especially for land parcels in Cluster 4. Refer to the CSLR technical Instructions [18], the quality of land data is classified into six levels based on the availability of four components: mapped land area, spatial measurement letter, textual measurement letter, and land book (Table 1).

Table 1. Types of land area data quality

Class	Mapped Land Area	Spatial Measurement Letter	Textual Measurement Letter	Land Book
Quality 1	Available	Available	Available	Available
Quality 2	Available	Unavailable	Available	Available
Quality 3	Available	Unavailable	Unavailable	Available
Quality 4	Unavailable	Available	Available	Available
Quality 5	Unavailable	Unavailable	Available	Available
Quality 6	Unavailable	Unavailable	Unavailable	Available

Source: CSLR Technical Instruction, 2019 [25]

The quality of land parcel data is classified into six levels based on the availability and completeness of four key components: mapped land area, spatial measurement letter, textual measurement letter, and land book, as shown in Table 1. Quality 1 represents the highest level of data quality, where all components are available and fully documented. Quality 2 indicates that the land parcel has been mapped and recorded in the land book, but the spatial measurement letter is not available. Quality 3 refers to parcels that have mapped land areas and land books but lack both spatial and textual measurement letters. Quality 4 indicates that the land parcel has not yet been mapped, although measurement documents and the land book are available. Quality 5 represents parcels where the mapped land area and spatial measurement letter are unavailable, but textual measurement letters and land books exist. Quality 6 represents the lowest level of data completeness, where only the land book is available, while the spatial data and measurement documents are missing. This classification helps identify the completeness and reliability of land administration data within the CSLR program.

As shown in Table 1, data quality types 4, 5, and 6 are classified as Cluster 4. These land plots have legal recognition (certificates and land book entries), but it is not spatially integrated with the registration map. Consistent with the Fit for Purpose Land Administration framework [26], this level of quality represents points along the spatial quality continuum, where minimal data (Quality 6) can still provide some tenure security, but full integration (Quality 1) is necessary for complete legal certainty and sustainable land governance.

The implementation of land registration in Indonesia has evolved across three periods, each with distinct technical standards and institutional arrangements.

In the first period (1960–1997), land registration was implemented pursuant to the mandate of the Basic Agrarian Law (Law No. 5 of 1960) [27], further regulated by Government Regulation Number 10 of 1961 [28]. This period was the most crucial milestone in Indonesian agrarian law, marking a transition from the colonial to the national system. This period targeted the elimination of the dualism between Western law and customary law, towards a single national land law based on improved customary law. During this period, the government was required by law to organize land registration nationwide. Land registration is carried out manually, with measurements taken using a simple mechanical chain of measurement or a theodolite, as well as soil books and survey letters written in special ink.

The second period (1997–2009), followed the enactment of Government Regulation Number 24 of 1997 [29]. The enactment of the Government Regulation after Government Regulation Number 10 of 1961 concerning Land Registration is considered to no longer be able to support the achievement of more tangible results in national development. The fundamental changes through Government Regulation (Peraturan Pemerintah/PP) No. 24 of 1997 were 1) the enactment of the granting of numbers to land plots that had been registered; and 2) the use of basic registration maps and registration maps that had been bound to technical base points with coordinates obtained from a measurement and calculation in a certain system that functioned as control points or binding points to measure and reconstruct boundaries. During this period, Land Office Computerization (LOC) began to be implemented as part of the land administration modernization project supported by the World Bank through the Land Administration Project (LAP). The LOC is driven by the urgent need to modernize land administration in Indonesia, which previously relied on manual processes. LOC has not been implemented throughout Indonesia.

The third period (2010–2023). The next critical period began in 2010. Along with technological development, the LOC application was later expanded into a more comprehensive, centralized system, the Computerized Land Office (KKP), which was later updated again to Geo-KKP in 2010 to integrate textual and spatial data in real time. The launch of the MPA aims to create uniform, transparent, and accurate service standards across all Land Offices in Indonesia. A massive migration from desktop-based applications to MPA-Web was completed in 2015 to support electronic certificate services.

The distribution of Cluster 4 land plots in Semarang City, based on the issuance period of the certificate, reveals an important pattern regarding the historical roots of current data quality problems. The differences between the periods are shown in Table 2.

Table 2. Number of Cluster 4 based on certificate issuance period in Semarang City

Period	Number of Land Plots Cluster 4	Percentage (%)
Up to 1997	54,333	62.3
1998–2009	21,671	24.9
2010–2023	5,473	6.3
ND*	5,707	6.5
Total	87,184	100

Source: Data processing (2023).
Note: ND*: No data.

The dataset used in this study was obtained from the Semarang City Land Office database of the CSLR program. The dataset represents the most recent available records, with a cutoff date of August 2023, when the data were extracted and processed for analysis.

The majority (62.3%) of Cluster 4 problems originated from the first period of land registration (1960–1997). These findings align with institutional theories that posit that path dependence – the historical institutional arrangements shaping current outcomes–plays an important role in land administration [30]. Certificates issued during this period were produced manually without proper georeferences, creating a legacy of data issues that persist to this day.

The number of Cluster 4 land plots decreased substantially in each subsequent period, from 54,333 plots (1960–1997), to 21,671 plots (1998–2009), to 5,473 plots (2010–2023). This downward trend indicates an improvement in spatial quality in land registration systems over time, alongside the introduction of coordinate-based mapping and digital systems. These results are consistent with previous study [31].

The plots marked as ND (no data), totaling 5,707 fields, represent certificates issued during periods where the digitization of the issuing record was incomplete. This plot of land is estimated to date from 1960 to 1997, when manual records were not fully maintained (field records, August 2023). 6.5% of land plots with unverifiable publication years highlight the challenges of data migration and historical record-keeping, supporting the observations from the study [32-34], which show that the data conversion process often leads to errors and loss of information.

The dominance of certification issues in Semarang City reflects the findings from Ethiopia, where Mengesha et al. [11] report that historical certification systems create a similar lack of spatial data. But while Ethiopia's solution emphasizes community-based land demarcation in rural areas, Semarang's urban context requires a different approach due to higher land values, denser settlement patterns, and more complex land markets.

3.2 Constraints in resolving Cluster 4 overlapping certificates

The fishbone diagram analysis reveals several technical and non-technical obstacles that hinder the completion of overlapping certificates in Semarang City. Figure 1 presents a comprehensive fishbone diagram, followed by a detailed explanation of each constraint category.

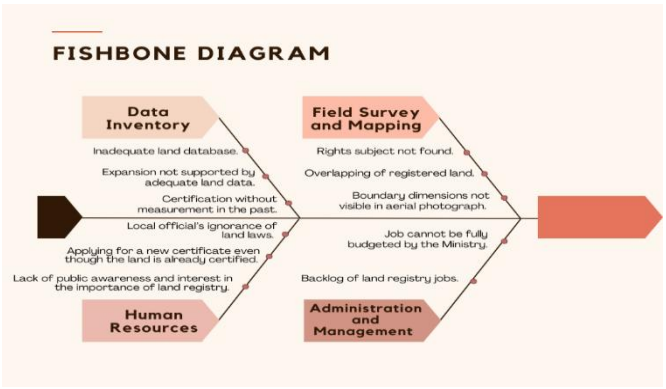

Figure 1. Fishbone diagram of the obstacles causing the overlapping Complete Systematic Land Registration (CSLR) certificates with old certificates (Cluster 4)

Technical Constraints

1) Data inventory

The fishbone analysis identified the following three main causes of data inventory problems.

a. Inadequate land database. The land cadastral database at the Semarang City Land Office contains significant gaps and inaccuracies. Based on the FGD results, certificates issued in the 1980s were issued without a proper survey, based solely on information from village heads or local community leaders. Incomplete information on past certification practices contributes to the difficulties in today's data improvement efforts.

b. Expansion into areas not supported by high-quality land data. The city of Semarang has undergone several changes and expansions of administrative boundaries. However, these changes are not accompanied by systematic updating of land data. An FGD participant explained that when there is an expansion or change in village boundaries, administrative records are updated, but not accompanied by adjustments to spatial data. As a result, there are differences in administrative data that make integration difficult.

c. Certification without proper measurements. Many certificates before 1997 were issued without technical measurements. When a conversion to a digital system occurs without additional surveys, it becomes a weakness in the accuracy of land data. This contributes to spatial data inconsistencies.

2) Field survey and mapping

Observations in the field revealed several obstacles during the survey activities, which are as follows.

a. The rights holder was not found. During field surveys, survey teams are often unable to locate landowners. This happens for various reasons: the landowner is working at the time of the survey, the property is rented to a tenant who lacks authority to confirm the boundary, or the landowner is not present because of a domicile outside the city of Semarang. In addition, some landowners refused to allow boundary measurements or confirmations. FGD participants shared that landowners sometimes worry if official measurements will lead to property tax increases or reveal discrepancies between the area of the certificate and the actual area.

b. Overlap during mapping. When survey data is plotted on a registration map, it often overlaps with existing certificates. This confirms that the root cause is the historical absence of old certificates from spatial databases.

c. Unclear boundary markers. Many plots of land lack permanent boundary markers, making it difficult to determine the exact boundary during the survey. Meanwhile, the landowner is legally obliged to install a marker. In addition, aerial photo maps used for mapping sometimes show unclear boundary markers due to vegetation, shadows, or poor image resolution. This makes accurate digitization difficult and requires additional field verification.

Non-Technical Constraints

1) Human resources

a. Ignorance of local officials about land law. Village and sub-district officials, who play a key role in legalizing land ownership and facilitating registration, often lack adequate knowledge of land laws and registration procedures. A participant in the FGD said that some village heads still issue ownership deeds without checking existing certificates because they do not understand that the land may already be

certified.

b. Low public awareness of the importance of land registration or the consequences of unregistered or overlapping certificates. Some view certificates as merely administrative documents rather than legal protection for their primary assets.

These findings align with Yubaidi et al. [35], who found that limited public understanding of the benefits of land registration led to low awareness and perpetuated unregistered land. Wicaksono et al. [36] also noted that the lack of local knowledge of land law significantly hampered the effectiveness of land registration programs in Indonesia.

2) Administrative and management

Workload accumulation

a. The Semarang City Land Office faces a significant imbalance between the high volume of land registration applications and the available staff. FGD participants reported that the routine work of issuing certificates left limited time for systematic data improvement. The national target for completing Cluster 4 far exceeds the government's (Ministry of Agrarian Affairs and Spatial Planning) current capacity. As one FGD participant explained, if we rely solely on the central government budget, it will take decades to solve all the problems in Cluster 4 in Semarang City. The technical staff at the Land Office are unable to adequately balance routine tasks with data improvement, resulting in slow data improvement efforts.

b. Comprehensive land data improvement requires significant financial resources. The central government budget allocated for the completion of Cluster 4 is insufficient to overcome the scale of the problem in Semarang City. These findings echo the observation that budget constraints are an obstacle to accelerating the resolution of Cluster 4 nationally.

3.3 Resolution strategies for Cluster 4 overlapping certificates

In response to the constraints identified and informed by the integrated theoretical framework presented in Figure 1, the next step is to propose 4 interconnected strategies to improve the quality of Cluster 4 land data. These strategies are designed to address technical and non-technical constraints while aligning with SDG priorities and land administration principles. This strategy is proposed systematically as shown in Figure 2 with the following explanation.

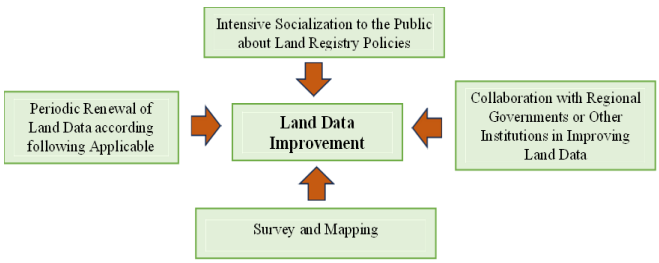

Figure 2. Optimization of land data improvement

Improving physical and legal land data is necessary to complete CSLR certificates that overlap with old certificates (Cluster 4). This activity has been carried out by all Land Offices in line with CSLR implementation across Indonesia to date. The Ministry of Agrarian Affairs and Spatial Planning has formulated a policy to accelerate systematic (not sporadic) land mapping from village to village, data collection by identifying land boundary points on photo maps, and the accurate completion of land metadata. Optimizing the implementation of land data improvement requires several efforts, as shown in Figure 2.

1) Periodic updating of land data in accordance with the applicable toponymy

The dynamics of regional autonomy are among the root causes of the overlap between CSLR land certificates and old certificates (Cluster 4). The expansion of the territory has caused some unrest in the community due to the administrative problems it triggers. Changes in the region become a problem on the land because they must be balanced with changes in the land's physical data. This problem is due to the public's ignorance of changes in land registration resulting from regional expansion.

Updating land data following toponymy is very important, without eliminating previous toponymy information. Maintenance of land registration data is carried out when there is a change in the physical or legal data of the registered land registration object. Then the relevant rights holder is obliged to register the changes as previously referred to the Head of the Land Office. Therefore, rights holders are required to register changes to both physical and legal data. Physical data is information about the location, boundaries, and area of the land and apartment units listed, including whether buildings or parts of buildings exist on them. Meanwhile, legal data is information about the legal status of registered land plots and apartment units, the rights holders, the rights of other parties, and other burdens.

The government is also obliged to educate the public to immediately re-register changes to physical data, especially those related to regional expansion. This socialization was carried out to increase awareness and encourage the community to immediately update their land physical data. The change is registered by attaching information from the sub-district where the land is located and about the expansion of the area concerned. After socialization, an active role by the community is needed to create an up-to-date land database. In addition, strong government regulations are needed to encourage people to immediately update physical data after regional expansion.

This strategy addresses institutional weaknesses in enforcement mechanisms identified in institutional theory, namely, ensuring that formal rules on data updates are actually implemented. This also follows the Fit for Purpose principle by gradually improving the quality of the land database. As with the cadastral model applied in the Netherlands, updating land data allows for the storage of relevant data in the form of information layers that will still provide new insights while remaining connected to previous information [37].

2) Intense socialization to the community regarding land registration policy

The general public's ignorance of land certificates and laws has led many people to apply for new certificates that are not in accordance with applicable regulations, such as applying for new certificates for old certificates that are damaged, lost, mortgaged, or issued for certain advantages. This is exacerbated by the initiative, outside the regulations, to issue certificates by the head of the village/sub-district in the context of issuing certificates, both intentional and unintentional.

Optimizing socialization on the importance of land certification and laws needs to be conveyed to the community, as well as the consequences of issuing certificates that do not

comply with applicable regulations. Innovative solutions are needed to address these challenges, such as the use of technology and collaboration with local communities, to ensure the accuracy and completeness of land databases. By having knowledge of various regulations regarding certificates, the community is expected to be more compliant with applicable laws and regulations, thereby enhancing the certainty of legal rights to the land they own.

This strategy addresses the normative and cultural-cognitive pillars of the institution [38], forming societal norms and understandings of land registration. In line with experience in Ghana, which showed that the involvement of regional heads and community leaders in socialization efforts increased registration rates by up to 45% in the pilot area [39]. Studies by Abab et al. [40] and Sarah et al. [41] strengthen the strategy that the attitude and subjective norms of the regional head have a significant effect on influencing the level of awareness and intention of the community in land registration.

3) Cooperation with local governments or other government agencies to improve land data

The national target for CSLR completion is set out in the Ministry of Agrarian Affairs and Spatial Planning's annual strategic plan. If carried out in accordance with the national strategic plan, the CSLR activities of the Semarang City Land Office will not be completed quickly. Therefore, the Semarang City Land Office innovates by fostering cooperation through a grant scheme funded by the Regional Revenue and Expenditure Budget (APBD). Using grant funds, CSLRs are projected to be completed between 2021 and 2023. CSLR acceleration activities are expected to minimize land disputes in Semarang City.

After solving the funding problem through the grant scheme, the next step for the Semarang City Office is to register land plots with complete measurements. Complete measurements are carried out through a program called Complete Cities or Complete Villages. Complete village measurements include all plots of land, measured in both physical and legal data formats. The Complete Village process begins with agreement on field boundaries, followed by field measurements, the creation of field maps, and the announcement of the results to the public. The fulfillment of the principle of publicity through the announcement of all land plots that have been measured in the form of village maps. The announcement was not only the result of measurements but also the registration of a piece of land.

Legal certainty of land rights cannot be achieved solely by the Ministry of Agrarian Affairs and Spatial Planning, but requires contributions and support from local governments or local government agencies. Cooperation efforts with local governments or related agencies will be effective if they are carried out 1 year before CSLR implementation.

Learning from the implementation of the land data improvement cooperation carried out by the Semarang City Office, a similar scheme can be implemented to compile more accurate and valid land data that will support better future development. The cooperation program can be continued until the expected program targets are achieved and can even be sustainable in the context of comprehensive regional development.

It is worth noting the innovations carried out by the Semarang City BPN Office, in collaboration with the Semarang City Government, through grant-funded land registration activities. This method can be used to overcome the problem of limited funds. However, in practice, there will be many challenges in its implementation. In terms of regulation, a clear legal umbrella is needed to address the possibility of using distribution fees for land registration activities. Local governments should be informed that clarity on the land's status would create investment opportunities in the area. Collaboration between institutions is urgently needed here.

These findings are reinforced by research in Ghana that developed a cadastral data interoperability model with five key components, including inter-agency relationship structures and data standardization, which aims to facilitate sustainable land management [42].

4) Surveys and mapping

Maintaining spatial information is necessary to address the global challenges of urbanization and complex urban infrastructure. Current technological developments in remote sensing and geospatial information science provide a great opportunity to improve the quality of spatial data. Determining the appropriate spatial resolution for mapping is essential.

The list of land plots will be compiled after the survey and mapping. If Cluster 4 land is not found in the field (cannot be mapped) after collecting field data and gathering information from the community, then the area can be included in the list of KW4-KW6 that have not been mapped (Cluster 4). For land areas that show indications of overlap, mapping is still carried out and placed in a list of overlapping land areas.

This strategy directly addresses the technical constraints identified in fishbone analysis. This aligns with the Fit for Purpose principle by using appropriate technology that balances accuracy with cost-effectiveness. The study by Koeva et al. [43] shows that current technological developments in remote sensing and geospatial information science offer significant opportunities to improve the quality of spatial data. Unmanned Aerial Vehicle (UAV)-based mapping can reduce survey costs by 40-60% while maintaining sufficient accuracy for urban land registration.

3.4 Implementation plan for Cluster 4 resolution strategies

To provide clearer operational guidance for the proposed strategies, Table 3 presents an indicative implementation plan including the timeline, key resources, and expected results for each strategy. The first strategy, periodic land data updates according to toponymy, is expected to be implemented in the short to medium term (1–3 years) through the involvement of land office staff, updated administrative records, and the Geo-KKP system, aiming to ensure that spatial and legal land data remain consistent with regional administrative changes.

The second strategy focuses on continuous public socialization of land registration policies through collaboration with local governments, village officials, and community leaders in order to increase public awareness and reduce improper certificate applications. The third strategy emphasizes collaboration with local governments through alternative funding schemes such as regional budgets (APBD), supported by inter-agency coordination and regulatory frameworks, which is expected to accelerate the resolution of Cluster 4 cases and improve land data quality. Finally, the optimization of surveys and mapping in the medium to long term (2–5 years) requires adequate survey teams, the use of UAV or remote sensing technology, and GIS systems to facilitate the integration of old certificates into spatial

databases and reduce overlapping land parcels.

Table 3. Implementation plan for Cluster 4 resolution strategies

Strategy	Timeline	Key Resources	Expected Results
Periodic land data updates according to toponymy	Short–medium term (1–3 years)	Land Office staff, updated administrative records, Geo-KKP system	Updated spatial and legal land data aligned with regional administrative changes
Public socialization on land registration	Continuous	Local governments, village officials, community leaders, outreach programs	Increased public awareness and reduction of improper certificate applications
Collaboration with local governments	Medium term (2–4 years)	APBD funding, inter-agency cooperation, regulatory support	Accelerated resolution of Cluster 4 and improved land data quality
Optimization of surveys and mapping	Medium–long term (2–5 years)	Survey teams, UAV/remote sensing technology, GIS systems	Integration of old certificates into spatial databases and reduction of overlapping parcels

4. CONCLUSIONS

This study reveals that the problem of overlapping land certificates (Cluster 4) in Semarang City has deep historical roots, with 62.3% of problematic land plots originating from the first period of land registration (1960–1997). The declining trend in the number of Cluster 4 plots in subsequent periods indicates improvement in the land registration system over time, alongside the introduction of coordinate-based mapping and digitalization. However, the presence of 6.5% of plots with "no data" status indicates that the data conversion process from manual to digital systems still poses challenges, including errors and information loss, as confirmed by recent international studies.

The fishbone analysis identified two main categories of obstacles in resolving Cluster 4. Technical constraints include: (1) inadequate data inventory due to weak cadastral databases, regional expansion without spatial data updates, and past certification practices without technical measurement; (2) field survey difficulties due to rights holders not being found, measurement refusal, and unclear boundary markers; and (3) overlapping during mapping due to the lack of integration of old certificates in the spatial database. Non-technical constraints encompass: (1) human resource limitations, namely local officials' ignorance of land law and low public awareness of the importance of land registration; (2) work accumulation and imbalance between application volume and staff capacity; and (3) central government budget limitations for comprehensive Cluster 4 resolution.

Based on these findings, this study formulates four integrated and mutually reinforcing strategies: 1) periodic land data updates according to toponymy; 2) intensive socialization of land registration policies to the public; 3) collaboration with local governments through alternative funding schemes; and 4) optimization of survey and mapping processes using appropriate technologies.

These four strategies collectively contribute to achieving the SDGs. Cluster 4 resolution supports SDG 1 (no poverty) through certainty of land rights as an economic asset and access to capital; SDG 11 (sustainable cities and communities) through accurate spatial data for spatial planning and slum prevention; and SDG 16 (peace, justice, and strong institutions) through reduction of land disputes and strengthening transparent land institutions.

This study makes a theoretical contribution by integrating institutional theory, the Fit for Purpose framework, and SDG targets to analyze land data problems. In practice, the innovative collaboration scheme with local governments through regional budget funding has proven effective and can be replicated in other areas facing similar challenges, provided that a clear legal framework and sustainable commitment from all stakeholders are in place. The limitation of this study—focusing on a single city with the most severe problems—actually provides deep insights as a critical case that can be analytically transferred to other contexts with adjustments according to local characteristics.

The success of Cluster 4 resolution ultimately depends on the synergy between institutional strengthening (formal rules), cultural transformation (public awareness and participation), and technological innovation (precision mapping). This holistic approach not only resolves past administrative problems but also builds a foundation for resilient land governance to support sustainable development in the future.

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