

Article

Benchmarking Indonesian Land Parcel Data Quality Regulations Against ISO 19157:2013 and International Geospatial Quality Frameworks: A Regulatory Gap Analysis

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Abstract

Geospatial data quality assurance is fundamental to effective land administration, yet regulatory frameworks vary significantly in their incorporation of internationally recognized quality concepts. This study conducts a systematic regulatory gap analysis assessing the extent to which Indonesian land registration regulations incorporate the quality concepts, measures, evaluation procedures, and reporting requirements defined by ISO 19157:2013. Employing a mixed-methods approach combining qualitative document analysis with a quantitative four-level scoring rubric across ten quality dimensions, we benchmark six Indonesian regulatory instruments against ISO 19157 and five international geospatial quality frameworks (INSPIRE, FGDC, ANZLIC, OGC, and OSM). Results reveal that the Indonesian regulatory framework achieves only 37% overall compliance (11/30 points), compared to 100% for ISO 19157 and INSPIRE, 77% for ANZLIC, 73% for FGDC, 67% for OGC, and 53% for OSM. Critical regulatory gaps exist in temporal quality, usability, lineage documentation, metadata integration, conformance testing, and quality assurance documentation. Inter-rater reliability analysis (Fleiss' Kappa = 0.78–0.82) confirms the robustness of the scoring process. Based on these findings, we propose a phased, context-appropriate reform roadmap comprising five recommendations with short-term (Year 1), medium-term (Years 2–3), and long-term (Years 4–5) implementation timelines for achieving regulatory alignment with international standards. This regulatory baseline provides the essential foundation for subsequent empirical assessments of cadastral data quality in Indonesian land administration.

Keywords: geospatial data quality; ISO 19157; land administration; cadastral mapping; Indonesia; quality assurance; land registration; regulatory framework



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1. Introduction

1.1. Global Importance of Geospatial Data Quality in Land Administration

Geospatial data quality is a foundational pillar of effective land administration systems worldwide. Land administration encompasses the processes of recording, securing, and disseminating information about the ownership, value, and use of land and its associated resources [1]. At the core of these systems lie cadastral datasets, authoritative spatial representations of land parcel boundaries, ownership rights, and related attributes [2], that underpin property taxation, land markets, urban planning, infrastructure development, and environmental management [3,4]. The fitness-for-purpose of cadastral data directly

determines the reliability of legal decisions, the efficiency of land transactions, and the equity of resource allocation across society [5].

Poor geospatial data quality in land administration manifests in multiple dimensions: incomplete coverage of land parcels, positional inaccuracies in boundary coordinates, logical inconsistencies such as overlapping or gapped polygons, outdated temporal information, inadequate documentation of data lineage, and insufficient metadata to support data discovery and reuse [5,6]. These quality deficiencies generate cascading consequences: disputed property boundaries leading to protracted legal conflicts, inefficient land markets due to uncertain tenure security, inequitable taxation from incomplete parcel inventories, and compromised spatial planning decisions based on unreliable base maps [7,8]. In developing economies undergoing rapid urbanization and land tenure formalization, the stakes are particularly high, as millions of citizens depend on land registration systems to secure their property rights and access credit markets [9,10].

Recognizing these challenges, the international geospatial community has invested decades of effort in developing standardized frameworks for assessing and communicating data quality. The International Organization for Standardization (ISO) Technical Committee 211 (Geographic Information/Geomatics) has produced a suite of standards addressing data quality, metadata, and quality evaluation procedures, with ISO 19157 serving as the cornerstone specification for geospatial data quality [11]. Concurrently, regional and domain-specific initiatives, including the European Union's INSPIRE Directive [12], the United States Federal Geographic Data Committee's Content Standard for Digital Geospatial Metadata (FGDC CSDGM) [13], the Australia and New Zealand Land Information Council's (ANZLIC) metadata profile [14], the Open Geospatial Consortium's (OGC) interoperability standards [15], and community-driven quality assurance practices in OpenStreetMap (OSM) [16], have operationalized quality principles in diverse institutional contexts.

Despite this rich international landscape, significant heterogeneity persists in how national governments translate quality standards into regulatory requirements for the production of cadastral data. Many countries have adopted ISO standards nominally but lack detailed technical regulations that operationalize quality elements into measurable specifications, validation procedures, and conformance testing protocols [17,18]. This implementation gap is especially pronounced in countries with legacy cadastral systems, resource constraints, and competing policy priorities, such as rapid land registration coverage [19,20]. Understanding the alignment, or misalignment, between national regulations and international quality standards is therefore essential for diagnosing systemic weaknesses, guiding regulatory reform, and enabling cross-border data interoperability [21,22].

1.2. ISO 19157:2013/2023—The International Standard for Geospatial Data Quality

ISO 19157, titled Geographic Information—Data Quality, is the authoritative international standard for describing, measuring, evaluating, and reporting the quality of geographic datasets. First published in 2013 and updated in 2023 as ISO 19157-1 (Part 1: General requirements), the standard provides a comprehensive framework comprising quality elements, sub-elements, quality measures, and evaluation procedures applicable to vector, raster, and point cloud geospatial data [23]. ISO 19157 defines quality as “the totality of characteristics of a product that bear on its ability to satisfy stated and implied needs” and structures quality assessment around seven core quality elements:

1. Completeness

Completeness addresses the presence or absence of features, their attributes, and relationships in a dataset relative to the abstract universe of discourse. It comprises two sub-elements: commission (excess data present that should not be) and omission

(data absent that should be present). In cadastral contexts, completeness is assessed through parcel coverage inventories, attribute field population rates, and comparison against authoritative source documents. Quality measures include the percentage of missing parcels, the percentage of parcels with complete attribute sets, and spatial coverage ratios. Completeness is critical for land administration because incomplete parcel inventories undermine equity in property taxation, transparency in the land market, and the reliability of spatial planning [5,11,24–26].

2. Logical Consistency

Logical consistency evaluates the fidelity of data to logical rules of the data structure, attribution, and relationships. Sub-elements include conceptual consistency (adherence to the conceptual schema's rules), domain consistency (adherence to value domains), format consistency (adherence to the physical structure), and topological consistency (correctness of topological characteristics). For cadastral parcels, topological consistency is paramount: parcels must not overlap, must not contain gaps (except where intended, such as roads or water bodies), and must form a planar partition of space. Automated topology validation tools detect violations such as self-intersecting polygons, duplicate vertices, and invalid ring orientations. Logical inconsistencies in cadastral data lead to legal ambiguities, duplicate registrations of land rights, and computational errors in area calculations [4,26–28].

3. Positional Accuracy

Positional accuracy quantifies the closeness of reported coordinate values to their true positions, either absolute (relative to a geodetic reference frame) or relative (between features within the dataset). Sub-elements include absolute or external accuracy and relative or internal accuracy. Positional accuracy is typically assessed by comparing sampled feature coordinates with higher-accuracy reference data (e.g., geodetic control points, high-precision GNSS surveys) and reported as root mean square error (RMSE), circular error probable (CEP), or linear error at 95% confidence (LE95) [29,30]. In cadastral mapping, positional accuracy directly affects boundary dispute resolution, alignment with orthoimagery and other base maps, and legal defensibility of parcel coordinates [29]. National mapping agencies commonly specify positional accuracy requirements as a function of map scale or land value class [30].

4. Thematic Accuracy

Thematic accuracy assesses the correctness of quantitative, non-quantitative, and classification attributes [31]. Sub-elements include classification correctness (comparison of classes assigned to features with reference data), non-quantitative attribute correctness, and quantitative attribute accuracy. For cadastral data, thematic accuracy applies to attributes such as land use classification, ownership type, parcel area, and administrative jurisdiction codes. Quality measures include confusion matrices, percentage of correctly classified parcels, and attribute error rates. Thematic inaccuracies in cadastral databases can lead to erroneous property valuations, misallocation of land-use permits, and flawed statistical analyses for policy-making [31–33].

5. Temporal Quality

Temporal quality characterizes the temporal attributes and temporal relationships of features. Sub-elements include the accuracy of time measurements (correctness of temporal references), temporal consistency (correctness of ordered events or sequences), and temporal validity (validity of data with respect to time) [11]. In land administration, temporal quality encompasses the currency of parcel data (time since last update), the accuracy of transaction timestamps (e.g., date of ownership transfer), and the maintenance of historical versions for legal traceability [31,34]. Outdated cadastral data undermines land market efficiency, complicates dispute resolution, and

impairs monitoring of land use change [35]. ISO 19157 recommends documenting data capture dates, update frequencies, and version histories in metadata.

6. Usability

Usability (introduced explicitly in ISO 19157:2013) evaluates the fitness of a dataset for a specific application or user requirement [36]. Sub-elements include fitness for purpose (the degree to which data meet user needs) and data quality metadata (the availability and comprehensiveness of quality information). Usability is inherently context-dependent: cadastral data suitable for regional planning (scale 1:10,000) may be inadequate for engineering design (scale 1:500) [37]. Quality measures for usability include user satisfaction surveys, task completion success rates, and maturity assessment matrices [18]. Communicating usability through standardized quality reports enables data producers to manage user expectations and data users to make informed fitness-for-purpose decisions [17,38].

Furthermore, lineage documents the provenance of data, including source materials, production processes, and transformations applied. ISO 19157 treats lineage as a quality element because transparent documentation of data history is essential for assessing trustworthiness and legal defensibility [39]. Lineage information includes source document types (e.g., field survey sketches, aerial imagery, legal deeds), processing steps (e.g., digitization, coordinate transformation, edge-matching), responsible parties, and dates. In cadastral systems, lineage is critical for legal evidence: courts require documented chains of custody from field measurements to registered parcel boundaries [40]. Inadequate lineage documentation undermines data auditability and complicates error diagnosis during quality control [8].

ISO 19157 further specifies quality measures (quantitative expressions of quality, e.g., RMSE for positional accuracy), quality evaluation procedures (direct inspection, indirect evaluation, full inspection, sampling), and quality result reporting (structured formats for communicating quality outcomes). The standard mandates that quality information be documented in metadata conforming to ISO 19115 (Metadata) and ISO 19115-1 (Metadata—Part 1: Fundamentals), ensuring discoverability and machine-readability of quality descriptors [41]. Conformance to ISO 19157 requires that data producers declare which quality elements are evaluated, specify the measures and procedures used, report quantitative results, and provide metadata enabling users to assess fitness-for-purpose.

The 2023 revision (ISO 19157-1:2023) introduced modular extensions, refined definitions, and enhanced integration with ISO 19115-1:2014 metadata. However, it retained the seven core quality elements and fundamental evaluation principles [42,43]. For this study, we reference ISO 19157:2013 as the baseline standard, noting that the 2023 update does not alter the core element structure relevant to regulatory benchmarking.

1.3. International Quality Frameworks and Their Alignment with ISO 19157

Beyond ISO 19157, multiple international and regional frameworks have developed quality assurance principles and specifications for geospatial data, each reflecting distinct institutional contexts, policy objectives, and technical priorities. Understanding these frameworks and their alignment with ISO 19157 provides essential context for benchmarking national regulations.

1. INSPIRE Directive (Infrastructure for Spatial Information in the European Community)

The INSPIRE Directive (2007/2/EC), adopted by the European Parliament and the Council in 2007, establishes a legal framework for the creation of a European Union spatial data infrastructure to support environmental policy [12,43,44]. INSPIRE mandates that member states make spatial datasets and services conformant with common

data specifications, metadata profiles, and network services. The INSPIRE Data Specification on Cadastral Parcels (D2.8.I.6, version 3.1, 2014) explicitly aligns with ISO 19157, requiring data providers to document quality for all six ISO elements and to conduct conformance testing against defined acceptance criteria [45]. INSPIRE's quality model maps ISO 19157 elements to cadastral parcel theme requirements: completeness (parcel coverage and attribute population), logical consistency (topological validity, domain constraint adherence), positional accuracy (coordinate accuracy relative to specified reference systems), thematic accuracy (classification correctness for land use and administrative units), temporal quality (validity periods and update cycles), usability (fitness for cross-border data exchange), and lineage (source documentation and process steps). INSPIRE further mandates metadata conforming to ISO 19115/19139 and requires automated validation services to test datasets against technical guidelines.

2. FGDC Content Standard for Digital Geospatial Metadata (CSDGM)

The United States Federal Geographic Data Committee (FGDC) published the Content Standard for Digital Geospatial Metadata (CSDGM, FGDC-STD-001-1998) to standardize metadata for federal geospatial datasets [13]. CSDGM predates ISO 19157 (published in 1998 vs. 2013), but it addresses several overlapping quality concerns. The standard includes mandatory and optional metadata elements for Data Quality Information, comprising Attribute Accuracy (analogous to ISO thematic accuracy), Logical Consistency Report (narrative description of topological and attribute consistency tests), Completeness Report (description of selection criteria and omissions), Positional Accuracy (horizontal and vertical accuracy assessments), Lineage (source materials and process steps), and Cloud Cover (for remotely sensed data). CSDGM emphasizes narrative-quality reports rather than quantitative measures and does not explicitly address temporal quality or usability as distinct elements. While CSDGM has been widely adopted by U.S. federal and state agencies, its alignment with ISO 19157 is partial: positional accuracy and lineage are well covered, but temporal quality, usability, and structured quality measures are underspecified. The FGDC has since endorsed ISO 19115 as the U.S. metadata standard, but CSDGM remains in use for legacy datasets [42].

3. ANZLIC Metadata Profile

The Australia and New Zealand Land Information Council (ANZLIC) developed a metadata profile based on ISO 19115:2005 and AS/NZS ISO 19115:2005, tailored to Australasian geospatial data infrastructure requirements [14]. The ANZLIC Metadata Profile (version 2.0, 2015) incorporates ISO 19157 quality elements through ISO 19115-1:2014 metadata extensions, requiring documentation of completeness, logical consistency, positional accuracy, thematic accuracy, temporal quality, and lineage. ANZLIC emphasizes fitness-for-purpose and user-oriented quality communication, aligning with ISO 19157's usability element. The profile mandates structured quality reporting for datasets published in national and state spatial data catalogues, with specific guidance for cadastral and administrative boundary datasets. ANZLIC's alignment with ISO 19157 is strong, though implementation varies across Australian states and New Zealand agencies.

4. OGC Standards (Open Geospatial Consortium)

The Open Geospatial Consortium (OGC) develops open standards for geospatial interoperability, including Web Feature Service (WFS), Web Map Service (WMS), and GeoPackage encoding [15]. OGC standards do not redefine quality elements; rather, they provide mechanisms for encoding and exchanging quality metadata that conform to ISO 19115 and ISO 19157. For example, WFS 2.0 supports inclusion of ISO 19157

quality metadata in feature responses, enabling clients to assess fitness-for-purpose dynamically [10]. OGC's Quality of Service (QoS) specifications address service-level quality (availability, response time) but defer to ISO 19157 for data-level quality. OGC standards thus serve as interoperability enablers for ISO 19157-compliant quality information rather than independent quality frameworks [43].

5. OpenStreetMap (OSM) and Volunteered Geographic Information (VGI) Quality Assurance OpenStreetMap, the largest crowdsourced geospatial database, employs community-driven quality assurance practices distinct from formal standards [16]. OSM quality assessment relies on intrinsic indicators (internal consistency metrics such as completeness of attribute tags, topological validity, edit history analysis) and extrinsic validation (comparison against authoritative reference datasets) [36]. Studies have mapped OSM quality metrics to ISO 19157 elements: completeness (feature density, attribute completeness), logical consistency (topology checks via OSM Inspector and JOSM validator), positional accuracy (comparison with GPS traces and official datasets), thematic accuracy (tag correctness), and temporal quality (recency of edits) [33,45]. However, OSM lacks centralized conformance testing, formal quality certification, or mandatory quality documentation, reflecting its decentralized governance model [33]. OSM's quality is highly variable spatially and thematically, with urban areas and well-mapped features (roads, buildings) exhibiting higher quality than rural areas and specialized themes (land parcels, administrative boundaries) [36,46]. Despite these limitations, OSM demonstrates that community-based quality assurance can achieve fitness-for-purpose for many applications, and its intrinsic quality indicators offer lessons for low-resource cadastral mapping contexts [47].

1.4. Land Registration and Cadastral Data Quality—Global Practice

Land registration and cadastral mapping are among the most demanding applications of geospatial data quality principles, as they directly affect legal rights, economic transactions, and social equity [4,48]. The Land Administration Domain Model (LADM, ISO 19152:2012) provides a conceptual schema for land administration systems, emphasizing the spatial unit (parcel geometry), party (rights holder), and rights–restrictions–responsibilities (RRR) relationships [49,50]. Mentioned by Oosterom et. al., LADM explicitly references ISO 19157 for spatial data quality and ISO 19115 for metadata, underscoring the centrality of quality assurance in modern cadastral systems.

Global best practices in cadastral data quality, as documented by the International Federation of Surveyors (FIG), the World Bank, and UN-Habitat, emphasize several principles [3,9,51]:

1. Fitness-for-purpose over absolute accuracy: Cadastral data quality requirements should be scaled to the economic value of land, the density of development, and the intended use cases, rather than pursuing uniform high precision everywhere [1]. This principle underpins the “fit-for-purpose land administration” paradigm advocated by FIG and the World Bank for accelerating tenure security in developing countries.
2. Incremental improvement: Cadastral systems should support progressive quality enhancement, allowing initial registration with lower accuracy (e.g., imagery-based boundary approximation) followed by refinement through field surveys as resources permit.
3. Transparent quality documentation: All cadastral datasets should include metadata documenting positional accuracy, completeness, lineage, and temporal currency, enabling users to assess fitness-for-purpose and courts to weigh evidence appropriately [18].

4. Automated quality control: Topology validation, attribute domain checks, and positional accuracy testing should be integrated into cadastral production workflows to detect errors early and reduce manual inspection costs [26].
5. Conformance testing and certification: Cadastral datasets should undergo formal conformance testing against technical specifications before legal registration, with quality certificates archived as part of the land record [19].

Empirical studies of cadastral data quality across diverse countries reveal recurring challenges. In Poland, a comprehensive assessment of parcel boundary data identified significant positional discrepancies between field survey coordinates and registered boundaries, attributed to legacy analog-to-digital conversion errors and inadequate quality control during mass digitization. In Latvia, an evaluation of cadastral vector data found high logical consistency (few topological errors) but poor thematic accuracy in land-use classifications and an incomplete attribute population [6]. In Brazil, quality control audits of large-scale urban cadastral data revealed that inadequate positional accuracy testing during acquisition led to systematic coordinate errors affecting property taxation. In Greece, model-driven engineering of the Hellenic Cadastre to conform with LADM and INSPIRE standards required extensive data cleaning to address completeness and logical consistency deficiencies in legacy datasets [5,7,19].

These case studies underscore that even countries with established cadastral systems face persistent quality challenges, often rooted in inadequate regulatory specifications, insufficient quality-control resources, and gaps between formal standard adoption and operational implementation [5,20].

1.5. Indonesian Land Administration Context and Regulatory Landscape

Indonesia, the world's fourth most populous nation with over 270 million people, faces immense land administration challenges rooted in the sheer scale of its parcel inventory. Early estimates placed the total number of land parcels at approximately 55 million (PP No. 24/1997) [50]; however, by 2017, the Ministry of Agrarian Affairs and Spatial Planning/National Land Agency (ATR/BPN) had revised this figure upward to approximately 126 million parcels [51], reflecting more comprehensive cadastral mapping and population growth over two decades. Despite this scale, formal land registration remained critically low. As of 2018, only approximately 46% of parcels had been formally registered, leaving the majority of land rights legally unprotected and economically underutilised [10]. To address this deficit, the Indonesian government launched the Complete Systematic Land Registration program (PTSL, Pendaftaran Tanah Sistematis Lengkap) in 2017 under Presidential Instruction No. 2/2018, with an initial target of registering all parcels by 2025. The PTSL program has since achieved remarkable quantitative progress: by January 2022, approximately 79.3 million parcels had been certified [51]; by mid-2024, the figure had reached 113.8 million registered parcels; and by December 2024, the Minister of ATR/BPN reported that 121 million parcels had been registered through PTSL, surpassing the annual target of 120 million, with 98 million parcels fully certificated, representing approximately 95% of the revised total parcel estimate [52,53]. The ATR/BPN has set a target of reaching 126 million registered parcels by 2025, effectively completing the national cadastral inventory. However, this rapid quantitative expansion has raised critical questions about the quality of registered data, particularly regarding positional accuracy, completeness, and lineage documentation, dimensions that are the focus of the present study [10,53,54].

A complex regulatory hierarchy governs Indonesia's land administration system:

1. UU No. 4/2011 tentang Informasi Geospasial (Law on Geospatial Information). This law establishes the legal framework for geospatial data production, management, and dissemination in Indonesia, designating the Geospatial Information Agency (BIG,

Badan Informasi Geospasial) as the national coordinating authority for geospatial standards. UU No. 4/2011 mandates that all geospatial data producers adhere to national standards and quality specifications, but delegates detailed technical requirements to implementing regulations [55].

2. PP No. 24/1997 tentang Pendaftaran Tanah (Government Regulation on Land Registration). PP No. 24/1997 is the foundational regulation for land registration procedures, specifying the roles of the Ministry of Agrarian Affairs and Spatial Planning/National Land Agency (ATR/BPN, Kementerian Agraria dan Tata Ruang/Badan Pertanahan Nasional), the types of land rights recognized, and the documentation required for registration [19]. The regulation addresses cadastral surveying requirements at a high level but lacks detailed quality specifications for spatial data [56].
3. Permen ATR/BPN No. 6/2018 tentang Pendaftaran Tanah Sistematis Lengkap (PTSL) Regulation.
This ministerial regulation operationalizes the PTSL program, emphasizing rapid, village-by-village systematic registration. Permen No. 6/2018 prioritizes registration coverage and simplifies documentation requirements to accelerate processing, but quality assurance provisions are minimal. The regulation allows the use of lower-accuracy measurement methods (e.g., handheld GPS, imagery interpretation) to expedite fieldwork, raising concerns about long-term data quality [57].
4. SNI ISO 19157:2015 (Indonesian National Standard for Geographic Information—Data Quality).
Indonesia formally adopted ISO 19157:2013 as a national standard (SNI ISO 19157:2015) through the National Standardization Agency (BSN, Badan Standardisasi Nasional) [58]. SNI ISO 19157:2015 is a direct translation of ISO 19157:2013, retaining all seven quality elements and evaluation procedures. However, SNI ISO 19157:2015 is a voluntary standard; its provisions are not automatically binding on government agencies unless explicitly referenced in regulations.
5. Peraturan Menteri Negara Agraria (PMNA) No. 3/1997 tentang Pendaftaran Tanah (Technical Standards for Land Registration).
This regulation, issued by the former National Land Agency (BPN, predecessor to ATR/BPN), specifies technical procedures for land registration, including field survey methods, map production, and quality control checklists. PMNA No. 3/1997 predates SNI ISO 19157:2015 and does not explicitly reference ISO 19157 elements [50].
6. Technical Guidance of PTSL Tahun 2017 and the KW Classification system.
The classification of land parcel data quality [59] (KW1 to KW6) within Indonesia's land administration system emerged as a structural response to the integration challenges between spatial (physical) and juridical (textual) datasets, which are fundamentally linked through key identifiers such as the Parcel Identification Number (NIB) and Survey Document Number (SU).

Historically, the evolution of this classification has been inseparable from the broader trajectory of land administration computerization within the National Land Agency (BPN/ATR). The initial phase, known as Land Office Computerization (LOC) (1997 to 2009), introduced digital spatial data management using Smallworld and Oracle Spatial, but lacked a standardized framework for assessing data quality [60]. Following the termination of the CIMSA contract, BPN developed the KKP Desktop system (circa 2009 to 2012), adopting the Land Administration Domain Model (LADM) and enabling centralized data architecture; however, spatial data remained inconsistently referenced, revealing significant integration gaps.

The subsequent development of Geo-KKP (circa 2012 to 2014) marked a critical turning point, as it enforced unified coordinate systems and enabled full integration of spatial and

textual data, thereby exposing discrepancies in data linkage and completeness. It was during this phase that the formal classification of data quality into six categories (KW1 to KW6) was introduced by the BPN Data and Information Center, distinguishing between “good quality” data (KW1 to KW3) and “incomplete or inconsistent” data (KW4 to KW6) based on the presence and integration of mapped parcels, spatial and textual survey documents, and land books [60,61].

Empirically, this transition revealed that of approximately 44.5 million registered parcels, only about 19 million met the criteria for good-quality data. At the same time, the majority (approximately 25.5 million) fell into lower-quality categories, highlighting systemic data inconsistencies [61,62]. The evolution continued with the implementation of KKP-Web (circa 2014 to 2016), which transformed the system into a web-based, real-time platform while maintaining the KW classification as a core feature for monitoring data quality through centralized dashboards.

The formal definition of KW1–KW6 was later codified in the Technical Guidelines for Complete Systematic Land Registration (PTSL) [59], where classification criteria are explicitly based on the availability and integration of four key components: mapped parcels, spatial and textual survey documents, and land books. Collectively, this historical trajectory demonstrates that the KW classification is not merely a technical categorization but a systemic artifact of Indonesia’s transition toward an integrated, digital land administration system [63].

In Indonesian cadastral practice, the *Gambar Ukur* (measurement sketch) is the field survey document that records parcel boundary coordinates, the survey method, and the surveyor assigned to the survey. The *Surat Ukur* (measurement certificate) is the official registered document derived from the GU, serving as legal evidence of parcel boundaries. Quality assurance traditionally focuses on verifying GU completeness, with limited systematic validation of spatial data quality elements [64].

Figure 1 uses color coding to indicate quality dimension coverage at each regulatory level: blue for primary law (UU No. 4/2011) mandating metadata integration; green/amber for ministerial regulations covering positional accuracy tiers and measurement methods (Permen ATR/BPN No. 6/2018, PMNA No. 3/1997); amber/partial for SNI ISO 19157:2015 (comprehensive but voluntary); and red/absent for operational guidance [65] which address data-integration completeness only. The hierarchy illustrates how quality-dimension coverage diminishes from conceptual framework to day-to-day operational guidance, identifying the regulatory layers where quality requirements are absent or incomplete.

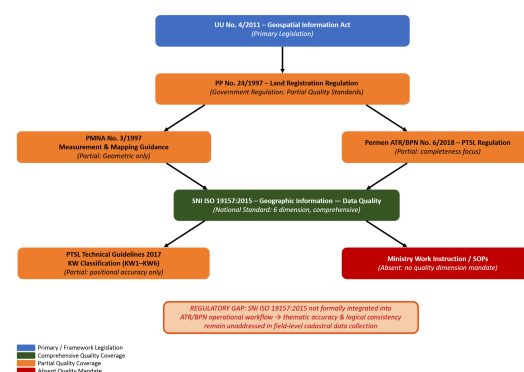


Figure 1. Hierarchical structure of the Indonesian regulatory framework for land data quality, annotated by quality dimension coverage (Green = comprehensive; Amber = partial; Red = absent).

1.6. Research Gap and Paper Objectives

A comprehensive review of the literature reveals a critical gap: no study has systematically benchmarked Indonesian land parcel boundary data quality regulations against

all seven ISO 19157 elements and compared Indonesia's regulatory framework with international quality frameworks (INSPIRE, FGDC, ANZLIC, OGC, OSM) in a structured, element-by-element manner. Existing studies are predominantly empirical case studies focusing on local or regional quality assessments, with partial coverage of ISO 19157 elements, typically emphasizing completeness, positional accuracy, and logical consistency while neglecting temporal quality, usability, and lineage. Regulatory discussions in the literature are anecdotal and operationally focused, lacking a systematic analysis of how Indonesian regulations map to international standards.

This gap is significant for several reasons. First, without a comprehensive regulatory gap analysis, Indonesian policymakers lack a clear roadmap for aligning national regulations with international best practices, hindering data interoperability and cross-border land administration cooperation (e.g., with ASEAN neighbors). Second, the absence of benchmarking obscures the specific regulatory deficiencies that undermine cadastral data quality, making it difficult to prioritize reform efforts. Third, the international land administration community lacks empirical evidence on how developing countries with large-scale land registration programs operationalize (or fail to operationalize) ISO 19157, limiting the generalizability of quality assurance frameworks.

This paper addresses these gaps through the following research objectives. It is important to note that this study assesses regulatory provisions for data quality—specifically, whether regulations define quality elements, specify measures, mandate evaluation procedures, and require quality reporting—rather than measuring actual cadastral data quality in the field. Regulatory coverage represents a necessary enabling condition for systematic quality assurance but is not sufficient to guarantee data quality in practice, which depends additionally on implementation capacity, institutional compliance, resource allocation, and operational enforcement:

1. Research Objective 1: Identify quality assurance principles in geospatial land data production adhering to global quality standards, specifically ISO 19157:2013 and international frameworks (INSPIRE, FGDC, ANZLIC, OGC, and OSM).
2. Research Question 1: Are the quality assurance principles and specifications for land parcels already optimal in land registration activities in Indonesia?
3. Hypothesis: Indonesian land registration regulations lack ISO 19157-compliant geospatial data quality assessment aspects, particularly in temporal quality, usability, lineage, conformance testing, and quality assurance documentation.

To address these objectives, this paper:

1. Conducts a comprehensive document analysis of Indonesian land registration regulations (UU No. 4/2011, PP No. 24/1997, PMNA No. 3/1997, Permen ATR/BPN No. 6/2018, SNI ISO 19157:2015, and Technical Guidance of PTSL 2017, including the KW classification system) to identify provisions related to each ISO 19157 quality element.
2. Develops a quantitative scoring matrix to assess the degree of alignment between Indonesian regulations and ISO 19157 across ten quality dimensions: the seven core elements (completeness, logical consistency, positional accuracy, thematic accuracy, temporal quality, usability, lineage) plus metadata integration, conformance testing, and quality assurance documentation.
3. Benchmark Indonesian regulations against five international frameworks (INSPIRE, FGDC, ANZLIC, OGC, OSM) using a common scoring matrix to contextualize Indonesia's performance.
4. Presents results through detailed regulatory analysis tables, cross-framework comparison matrices, and visual analytics (grouped bar charts, radar charts, heatmaps, and overall compliance scores).

5. Discusses the implications of the findings for Indonesian land administration reform, identifies specific regulatory gaps, and provides actionable recommendations to achieve ISO 19157 compliance.

The remainder of this paper is structured as follows. Section 2 describes the mixed-methods research design, data sources, analytical framework, and scoring rubric. Section 3 presents results, including detailed regulatory document analysis, cross-framework comparison, and a quantitative compliance assessment, with four figures and three tables. Section 4 discusses findings, interprets regulatory gaps, compares Indonesia with INSPIRE success factors, and offers five specific recommendations for regulatory improvement. Section 5 concludes with a summary of contributions and future research directions.

2. Materials and Methods

2.1. Research Design

This study employs a mixed-methods approach combining qualitative document analysis and quantitative scoring to benchmark Indonesian land parcel data quality regulations against ISO 19157:2013 and international frameworks [17]. The research design comprises four phases as shown in Figure 2.

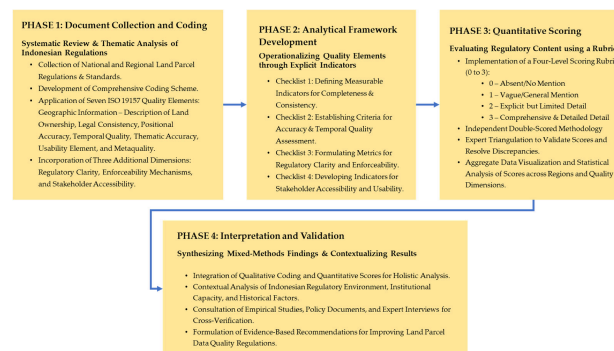


Figure 2. Research Design Process.

In Phase 1, Indonesian land registration regulations and international quality framework documents are systematically collected and reviewed. Each document was coded to identify provisions related to the seven ISO 19157 quality elements (completeness, logical consistency, positional accuracy, thematic accuracy, temporal quality, usability, lineage) and three additional quality dimensions (metadata integration, conformance testing, quality assurance documentation).

Then, in Phase 2, we developed a ten-dimensional analytical framework that operationalizes ISO 19157 elements and supplementary quality dimensions into assessable criteria. For each dimension, we defined explicit indicators of regulatory coverage, such as: Does the regulation define the quality element? Does it specify quantitative measures or thresholds? Does it mandate evaluation procedures? Does it require quality reporting in metadata? This framework enabled systematic comparison across regulations and frameworks [18]. In the third Phase, we applied a four-level scoring rubric (0 = None, 1 = Minimal, 2 = Partial, 3 = Full) to rate the degree of alignment between each regulation/framework and each quality dimension. Scores were assigned based on explicit criteria (detailed in Section 2.4) and validated through triangulation with literature and expert review. Aggregate scores were calculated for each regulation/framework and visualized through comparative charts.

Finally, in Phase 4, we interpreted quantitative scores in light of qualitative document analysis, identifying specific regulatory gaps and contextual factors (e.g., PTSL program priorities, resource constraints). The research validated its findings through comparisons

with empirical quality assessment studies in Indonesia and consultation with the land administration literature.

This mixed-methods design balances the rigor of quantitative benchmarking with the contextual richness of qualitative regulatory analysis, addressing the complexity of comparing legal frameworks across diverse institutional contexts.

2.2. Data Sources

2.2.1. Indonesian Regulatory Documents

We analyzed six key Indonesian regulations governing land registration and geospatial data quality:

1. UU No. 4/2011 tentang Informasi Geospasial (Law on Geospatial Information).
2. PP No. 24/1997 tentang Pendaftaran Tanah (Government Regulation on Land Registration).
3. Peraturan Menteri Negara Agraria (PMNA) No. 3/1997 tentang Pendaftaran Tanah (which is an implementation regulation for PP No. 24/1997).
4. Permen ATR/BPN No. 6/2018 tentang Pendaftaran Tanah Sistematis Lengkap (PTSL Regulation).
5. SNI ISO 19157:2015 (Indonesian National Standard for Geographic Information—Data Quality).
6. Petunjuk Teknis Pendaftaran Tanah Sistematis Lengkap (PTSL) Tahun 2017 (Technical Guidance of PTSL 2017).

These documents represent the complete regulatory hierarchy from national law (UU) through government regulation (PP) and ministerial regulations (Permen) to technical standards (SNI) and operational classification systems (Technical Guidance).

2.2.2. International Framework Documents

We analyzed authoritative specifications for five international quality frameworks:

1. ISO 19157:2013 Geographic Information—Data Quality.
2. INSPIRE Directive 2007/2/EC and INSPIRE Data Specification on Cadastral Parcels (D2.8.I.6, version 3.1, 2014).
3. FGDC Content Standard for Digital Geospatial Metadata (CSDGM, FGDC-STD-001-1998).
4. ANZLIC Metadata Profile (version 2.0, 2015) based on AS/NZS ISO 19115:2005.
5. OGC Standards: Web Feature Service (WFS) 2.0, Web Map Service (WMS) 1.3.0, and OGC Quality of Service specifications.
6. OpenStreetMap (OSM) Quality Assurance Practices: documented in OSM Wiki, academic literature on VGI quality assessment, and OSM validation tools (OSM Inspector, JOSM validator, version 18.x, 2024).

2.2.3. Supporting Literature

We reviewed 112 peer-reviewed papers and technical reports identified through systematic literature searches on ISO 19157 cadastral quality, INSPIRE implementation, FGDC/ANZLIC/OGC standards, OSM quality assessment, and Indonesian land administration. This literature provided context for interpreting regulatory provisions, validating scoring decisions, and identifying empirical findings from quality assessment.

2.3. Analytical Framework

The analytical framework operationalizes ISO 19157:2013 quality assessment by decomposing the standard's quality model into ten dimensions, each anchored to four diagnostic criteria that probe the depth and enforceability of regulatory provisions: (i) whether the dimension is defined in the regulation; (ii) whether quantitative measures or thresholds are specified; (iii) whether evaluation procedures are mandated; and (iv) whether reporting

requirements are explicit and obligatory. These four criteria mirror the structure of a complete ISO 19157 data quality element, which requires documenting a quality measure, an evaluation procedure, and a quality result in conformant metadata. By applying the same four-probe logic uniformly across all ten dimensions and all six regulatory frameworks under review, the framework enables systematic, reproducible, and cross-comparable regulatory gap analysis. The ten dimensions span both the six core ISO 19157 quality elements (Completeness, Logical Consistency, Positional Accuracy, Thematic Accuracy, Temporal Quality, and Usability) and four operationally critical meta-dimensions (Lineage, Metadata Integration, Conformance Testing, and Quality Assurance Documentation) that determine whether quality commitments in primary regulations are actually implemented, traceable, and verifiable in practice.

To translate qualitative documentary analysis into a quantifiable compliance index, we applied a four-level scoring rubric (0–3) to each dimension for each regulatory framework. The rubric is operationalized through four binary diagnostic criteria applied uniformly to each quality dimension: (C1) Definition: Is the quality dimension explicitly defined or referenced in the regulation? (C2) Measures: Are quantitative measures, thresholds, or indicators specified? (C3) Procedures: Are evaluation procedures mandated (not merely recommended)? (C4) Reporting: Are quality reporting requirements explicit, mandatory, and linked to standardized metadata? The aggregate score corresponds to the number of criteria satisfied: Score 0 (None) = no criteria met; Score 1 (Minimal) = C1 only met; Score 2 (Partial) = at least two criteria met (C1 + C2 or C1 + C3); Score 3 (Full) = all four criteria met. This operationalization ensures reproducibility by anchoring scoring decisions to specific textual evidence. It is important to note that ISO 19157:2013 functions as a conceptual and methodological framework rather than prescribing specific numerical thresholds applicable to all contexts. Our scoring recognizes this distinction: a Score of 0 is assigned only when a quality dimension is entirely absent from a regulation, not merely because numerical thresholds are unspecified. Scores were assigned independently by the authors through systematic document analysis and subsequently reconciled through structured discussion; ambiguous cases were resolved by consulting supporting literature and applying the principle of conservatism (lower score assigned when evidence was equivocal).

- A score of 1 (Minimal) is assigned when the dimension is acknowledged or implied. However, definitions are incomplete, no quantitative thresholds are set, evaluation procedures are not mandated, and reporting is absent or optional; a regulation that states only that “data should be accurate” without elaboration exemplifies this level.
- A score of 2 (Partial) is assigned when the dimension is defined. Some measures or procedures are specified, but coverage is incomplete, thresholds are not fully quantified, or requirements are recommended rather than mandatory; a regulation that defines positional accuracy and specifies RMSE thresholds for some, but not all, land classes, without mandating testing procedures, illustrates this level.
- A score of 3 (Full) is assigned only when the dimension is comprehensively defined, consistent with ISO 19157, quantitative measures and thresholds are specified for all relevant contexts, evaluation procedures are mandated and detailed, and reporting requirements are explicit, mandatory, and linked to standardized metadata formats such as ISO 19115.

Scores were assigned independently by the authors through systematic document analysis and subsequently reconciled through structured discussion; ambiguous cases were resolved by consulting supporting literature and applying the principle of conservatism. When evidence was equivocal, the lower score was assigned. The integrated framework and rubric are presented in Table 1.

Table 1. Scoring Framework for Regulation Assessment.

#	Quality Dimension	ISO 19157 Sub-elements	Assessment Criteria (4 Diagnostic Probes)	Score 0—None	Score 1—Minimal	Score 2—Partial	Score 3—Full
1	Completeness	Commission; Omission	(a) Defines completeness (omission/commission)? (b) Specifies completeness measures (% missing parcels, attribute population rates)? (c) Mandates evaluation procedures (sampling, source-document comparison)? (d) Requires completeness reporting in metadata?	Not mentioned; no operational guidance	Acknowledged but no definitions, measures, or reporting	Defined; some measures or procedures specified; not comprehensive or not mandatory	Comprehensively defined; quantitative thresholds; mandatory evaluation; ISO 19115-compliant reporting
2	Logical Consistency	Conceptual; Domain; Format; Topological	(a) Defines logical consistency sub-types (conceptual, domain, format, topological)? (b) Specifies topology rules (no overlaps, no gaps, valid polygons)? (c) Mandates automated topology validation? (d) Requires logical consistency reporting?	Not mentioned	Mentioned, but no topology rules, validation, or reporting	Defines some sub-types; some rules specified; validation not fully mandated	All sub-types defined; topology rules specified; automated validation mandated; reporting required
3	Positional Accuracy	Absolute external accuracy; Relative internal accuracy; Gridded data position accuracy	(a) Defines positional accuracy (absolute/relative)? (b) Specifies accuracy thresholds (RMSE, LE95) by land class or map scale? (c) Mandates positional accuracy testing (control-point comparison)? (d) Requires accurate reporting in metadata?	Not mentioned	Stated (“data should be accurate”) without definitions, thresholds, or testing	Defines accuracy; thresholds for some classes; testing not fully mandated	All sub-types defined; thresholds for all classes/scales; mandatory testing; metadata reporting
4	Thematic Accuracy	Classification correctness; Non-quantitative attribute correctness; Quantitative attribute accuracy	(a) Defines thematic accuracy (classification, attribute correctness)? (b) Specifies thematic accuracy measures (confusion matrix, attribute error rates)? (c) Mandates thematic validation procedures? (d) Requires thematic accuracy reporting?	Not mentioned	Implied but no measures, validation, or reporting	Defines thematic accuracy; some measures specified; validation not fully mandated	Comprehensively defined; quantitative measures; mandatory validation; reporting required
5	Temporal Quality	Accuracy of a time measurement; Temporal consistency; Temporal validity	(a) Defines temporal quality (time measurement accuracy, consistency, validity)? (b) Specifies temporal metadata (capture date, update frequency, version history)? (c) Mandates temporal quality evaluation? (d) Requires temporal quality reporting?	Not mentioned	Survey/registration dates recorded; no temporal quality measures, evaluation, or reporting	Temporal metadata partially specified; no mandatory evaluation or reporting	All temporal sub-elements defined; full metadata requirements; mandatory evaluation; reporting required
6	Usability	Fitness-for-purpose assessment	(a) Defines usability (fitness-for-purpose)? (b) Specifies usability assessment methods (user surveys, task success rates, maturity matrices)? (c) Mandates usability evaluation for different user classes? (d) Requires usability reporting?	Not mentioned	Implicit fitness assumption; no definitions, methods, or reporting	Defines usability; some assessment methods noted; not mandatory for all user classes	Comprehensively defined; assessment methods specified; mandatory multi-user-class evaluation; reporting required
7	Lineage	Source; Process step; Responsible party	(a) Defines lineage (source materials, process steps, responsible parties)? (b) Specifies lineage documentation requirements (source types, processing history)? (c) Mandates lineage capture in production workflows? (d) Requires lineage reporting in metadata?	Not mentioned	Survey records are kept, but no structured lineage definition, documentation standard, or reporting	Lineage is partially defined; some documentation requirements are not fully mandated in workflows	Comprehensively defined; full documentation requirements; mandatory workflow capture; ISO 19115 metadata reporting

Table 1. Cont.

#	Quality Dimension	ISO 19157 Sub-elements	Assessment Criteria (4 Diagnostic Probes)	Score 0—None	Score 1—Minimal	Score 2—Partial	Score 3—Full
8	Metadata Integration	ISO 19115/19139 conformance; Quality metadata elements; Encoding; Catalog publication	(a) Mandates metadata conforming to ISO 19115/19139 or equivalent? (b) Requires quality metadata elements (scope, measures, results)? (c) Specifies metadata encoding and exchange formats? (d) Mandates metadata publication in catalogs?	No metadata requirements	Metadata mentioned; no ISO conformance, quality elements, encoding, or catalog mandate	Metadata required; some ISO elements; encoding or catalog publication not fully mandated	Full ISO 19115/19139 conformance is mandated; quality elements, encoding, and catalog publication are all required
9	Conformance Testing	Dataset conformance testing; Acceptance criteria; Non-conformance consequences	(a) Mandates conformance testing against quality specifications? (b) Specifies testing procedures (automated validation, sampling, acceptance criteria)? (c) Requires conformance certificates or quality reports? (d) Defines non-conformance consequences?	No conformance testing of any kind	Implicit quality check; no formal testing procedures, certificates, or consequences defined	Some testing specified, procedures, or acceptance criteria are incomplete; consequences are not defined	Mandatory conformance testing; full procedures; certificates/reports required; non-conformance consequences defined
10	QA Documentation	Quality plans; Test reports; Audit trails; User accessibility	(a) Mandates structured QA documentation (quality plans, test reports, audit trails)? (b) Specifies documentation formats and content? (c) Requires archiving of QA documentation with land records? (d) Mandates QA documentation accessibility for users?	No QA documentation requirements	Ad hoc record-keeping; no structured QA plans, formats, archiving, or accessibility mandate	QA documentation partially required; formats or archiving not fully specified; accessibility not mandated	Comprehensive QA documentation mandated; formats specified; archiving required; user accessibility mandated

Note: ISO 19157 sub-elements follow ISO 19157:2013, Annex D [1]. Scoring criteria in columns 5 to 8 apply uniformly across all six regulatory frameworks assessed in this study (ISO 19157, INSPIRE, FGDC, ANZLIC, OGC, Indonesian regulations). The four diagnostic probes in column 4 operationalize the ISO 19157 data quality element structure: measure → evaluation procedure → result → metadata reporting. # = Sequential number of quality dimension.

2.4. Operationalized Scoring Protocol

The four-level scoring rubric (0–3) is operationalized through four binary diagnostic criteria applied uniformly to each quality dimension for each regulation/framework: (C1) Definition: Is the quality dimension explicitly defined or referenced in the regulation? (C2) Measures: Are quantitative measures, thresholds, or indicators specified? (C3) Procedures: Are evaluation procedures mandated (not merely recommended)? (C4) Reporting: Are quality reporting requirements explicit, mandatory, and linked to standardized metadata? The aggregate score corresponds directly to the number of criteria satisfied: Score 0 (None) = no criteria met; Score 1 (Minimal) = C1 only met; Score 2 (Partial) = C1 + C2 or C1 + C3 met (at least two criteria); Score 3 (Full) = all four criteria met. This operationalization ensures that scoring decisions are traceable to specific textual evidence within each regulation and minimizes subjective interpretation.

2.5. Validation and Limitations

2.5.1. Validation

The scoring was validated through four mechanisms:

1. Triangulation with empirical studies: We compared our regulatory assessments with findings from empirical quality assessment studies in Indonesia (e.g., PTSL quality audits, Kantah case studies) to verify that our interpretations of regulatory gaps align with observed quality deficiencies.
2. Literature cross-checking: We cross-referenced our interpretations of international frameworks (INSPIRE, FGDC, ANZLIC, OGC, OSM) with published comparative analyses and implementation studies to ensure consistency with established scholarly consensus. Inter-rater reliability assessment: The three authors independently scored all regulation/framework–dimension pairs prior to consensus discussion. For Table 2 (60 scoring decisions), initial independent scoring yielded Fleiss' Kappa = 0.78 (95% CI: 0.71–0.85), indicating substantial inter-rater agreement. For Table 3 (70 scoring decisions), Fleiss' Kappa = 0.82 (95% CI: 0.76–0.88), indicating substantial to almost perfect agreement. Pairwise Cohen's Kappa values ranged from 0.74 to 0.86. Disagreements were concentrated at the Score 1/Score 2 boundary (14 of 130 total decisions, 10.8%) and were resolved through structured discussion applying the conservative scoring principle.

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Table 2. Indonesian Regulatory Document Analysis Matrix.

Quality Dimension/Regulation	SNI ISO 19157:2015 (As Benchmark)	UU No. 4/2011 (Geospatial Information Law)	PP No. 24/1997 (Land Registration)	Permen ATR/BPN No. 6/2018 (PTSL)	PMNA No. 3/1997	Technical Guidance of PTSL 2017
Completeness	Full definition of completeness (omission/commission); measures and procedures specified	General mandate for “complete” geospatial data (Art. 8), but no definition or measures	Requires complete parcel documentation (Art. 19) but no spatial completeness specification	Emphasizes registration coverage targets; no spatial completeness measures	Requires complete field survey documentation (GU); no omission/commission measures	Checklist for document completeness; no spatial completeness measures
Logical Consistency	Full definition of logical consistency (conceptual, domain, format, topological); measures and procedures specified	No specific provisions	No specific provisions	No specific provisions	Requires valid parcel polygons (Art. 12); no topology validation procedures specified	Mentions “no overlaps” requirement; no validation procedures
Positional Accuracy	Full definition of positional accuracy (absolute/relative); measures and procedures specified	Mandates adherence to national accuracy standards (Art. 10), but no thresholds are specified	Requires “accurate” measurements (Art. 17) but no thresholds	Allows lower-accuracy methods (handheld GPS, imagery) for speed; no accuracy thresholds	Classification of base map class 1 (0.2–2 m), class 2 (0.3–3 m), and class 3 (0.5–5 m) based on map scale 1:1000 to 1:10.000 10,000	Specifies survey methods by land class; no quantitative accuracy thresholds
Thematic Accuracy	Full definition of thematic accuracy (classification, attribute correctness); measures and procedures specified	No specific provisions	Requires correct attribute recording (Art. 20) but no validation procedures	No specific provisions	Requires correct parcel area calculation (Art. 22); no thematic validation procedures	Checklist for attribute completeness; no accuracy validation
Temporal Quality	Full definition of temporal quality (time accuracy, consistency, validity); measures and procedures specified	Mandates data currency (Art. 11), but no temporal quality definition	Requires recording of registration date (Art. 21); no temporal quality measures	No specific provisions	Requires recording of survey date (Art. 23); no temporal quality measures	Requires date stamps; no temporal quality measures
Usability	Full definition of usability (fitness-for-purpose); assessment methods specified	No specific provisions	No specific provisions	No specific provisions	No specific provisions	No specific provisions
Lineage	Full definition of lineage (sources, processes, responsible parties); documentation structure specified	Mandates documentation of data sources (Art. 12), but no lineage structure is specified	Requires surveyor certification (Art. 18); no process lineage	Requires source document recording; no process lineage	Requires GU (field sketch) archiving; no process lineage documentation	Requires surveyor signature; no process lineage
Metadata Integration	Full metadata integration with ISO 19115/19139; quality metadata elements specified	Mandates metadata conforming to national standards (Art. 13); references SNI ISO 19115	No metadata requirements	No metadata requirements	No metadata requirements	No metadata requirements
Conformance Testing	Full conformance evaluation procedures specified	No specific provisions	No specific provisions	No specific provisions	No specific provisions	Quality control checklists; no formal conformance testing
QA Documentation	Full quality reporting structure specified	No specific provisions	Requires archiving of survey documents (Art. 24); no structured QA reports	No specific provisions	Requires archiving of GU and SU; no structured QA reports	Requires surveyor certification; no structured QA reports

Table 3. International and Indonesian Framework Compliance Scoring Matrix.

Quality Dimension/Framework	ISO 19157:2013	INSPIRE (Cadastral Parcels)	FGDC CSDGM	ANZLIC Metadata Profile	OGC Standards	OpenStreetMap (OSM)	Indonesia (ATR/BPN)
Completeness	3 (Full definition, measures, procedures)	3 (Mandatory completeness reporting, measures specified)	2 (Completeness report required, but narrative, not quantitative)	2 (Completeness metadata required, measures not fully specified)	2 (Completeness metadata supported, not mandated)	2 (Intrinsic completeness metrics used, but variable)	1 (Document completeness mentioned, no spatial measures)
Logical Consistency	3 (Full definition, all sub-elements, measures, procedures)	3 (Mandatory topology validation, domain checks)	2 (Logical consistency report required, narrative)	2 (Logical consistency metadata required, measures not fully specified)	2 (Topology validation supported via WFS, not mandated)	2 (Topology checks via OSM Inspector, JOSM, but not universal)	2 (Valid polygons required, no validation procedures specified)
Positional Accuracy	3 (Full definition, absolute/relative, measures, procedures)	3 (Mandatory positional accuracy testing, thresholds specified)	3 (Horizontal/vertical accuracy required, quantitative)	3 (Positional accuracy metadata required, quantitative)	2 (Positional accuracy metadata supported, not mandated)	2 (Positional accuracy assessed via GPS traces, reference data, but variable)	2 (KW1-KW6 accuracy tiers specified, testing not mandated)
Thematic Accuracy	3 (Full definition, classification/attribute correctness, measures, procedures)	3 (Mandatory thematic accuracy testing for classifications)	2 (Attribute accuracy report required, narrative)	2 (Thematic accuracy metadata required, measures not fully specified)	2 (Thematic accuracy metadata supported, not mandated)	2 (Tag correctness assessed, but variable)	1 (Correct attributes required, no validation procedures)
Temporal Quality	3 (Full definition, all sub-elements, measures, procedures)	3 (Mandatory temporal validity, update frequency reporting)	2 (Temporal currency mentioned, not structured)	2 (Temporal metadata required, quality measures not fully specified)	1 (Temporal metadata supported, minimal quality measures)	2 (Edit recency tracked, but no formal temporal quality measures)	1 (Survey date required, no temporal quality measures)
Usability	3 (Full definition, fitness-for-purpose, assessment methods)	3 (Mandatory fitness-for-purpose assessment, user feedback)	1 (Usability not explicitly addressed)	2 (Fitness-for-purpose metadata encouraged, not mandated)	2 (Service-level QoS addresses usability, data-level minimal)	1 (User feedback informal, no structured usability assessment)	1 (Fitness-for-purpose not addressed)
Lineage	3 (Full definition, sources, processes, responsible parties, structure)	3 (Mandatory lineage documentation, structured)	3 (Lineage required, sources, and process steps)	3 (Lineage metadata required, structured)	2 (Lineage metadata supported, not mandated)	1 (Edit history tracked, but not structured lineage)	1 (Source documents archived, no process lineage)
Metadata Integration	3 (Full integration with ISO 19115/19139, quality metadata elements)	3 (Mandatory ISO 19115/19139 metadata, quality elements)	3 (CSDGM mandatory, quality elements included)	3 (ISO 19115 metadata mandatory, quality elements)	3 (ISO 19115/19139 metadata supported via OGC standards)	2 (OSM tags serve as metadata, but not ISO-compliant)	1 (Metadata mandated by UU 4/2011, not implemented for cadastral data)
Conformance Testing	3 (Full conformance evaluation procedures, acceptance criteria)	3 (Mandatory conformance testing, automated validation services)	2 (Quality control recommended, not mandated)	2 (Quality control recommended, not mandated)	2 (Validation services available, not mandated)	1 (Community validation, no formal conformance testing)	0 (No conformance testing requirements)
QA Documentation	3 (Full quality reporting structure, quality reports mandatory)	3 (Mandatory quality reports, structured formats)	2 (Quality reports recommended, narrative)	2 (Quality reports recommended, structured)	2 (Quality reports supported, not mandated)	1 (Informal quality discussions, no structured reports)	0 (No structured QA documentation requirements)
Total Score (out of 30)	30	30	22	23	20	16	11
Percentage	100%	100%	73%	77%	67%	53%	37%

Note: Scoring scale: 0 = Non-existent; 1 = Poor; 2 = Moderate; 3 = Good/Complete.

2.5.2. Limitations

This study is a regulatory document analysis and does not incorporate empirical assessment of actual cadastral data quality through field measurements, dataset audits, or system-level testing. Consequently, our findings characterize the regulatory environment for quality assurance—specifically, what is mandated, what is recommended, and what is absent from legal and technical frameworks—rather than measuring data quality outcomes in practice. Regulatory provisions represent necessary but insufficient conditions for quality assurance; actual quality depends additionally on implementation capacity, resource availability, institutional compliance, and enforcement effectiveness. Future research should complement this regulatory baseline with empirical cadastral data quality assessments to determine the relationship between regulatory coverage and operational quality outcomes.

This study has several limitations:

1. Document-based analysis: Our assessment is based on written regulations and standards, not on actual implementation practices. Regulations may be more or less stringent than operational quality assurance in practice. Future research should complement this regulatory analysis with empirical audits of cadastral data quality and quality control workflows in Indonesian Kantah [5].
2. Scoring subjectivity: Despite explicit rubrics, some scoring decisions involve judgment, particularly in the “partial” vs. “minimal” distinction. We mitigated this through dual coding and conservative scoring, but some subjectivity remains.
3. Framework heterogeneity: The six frameworks compared (ISO 19157, INSPIRE, FGDC, ANZLIC, OGC, OSM) differ in scope, legal status, and institutional context, making direct comparison imperfect. We focused on quality element coverage rather than institutional factors, but contextual differences should be considered when interpreting results.
4. Temporal scope: This analysis reflects regulations as of 2023. Indonesian regulations are evolving, and future updates (e.g., revisions to Permen ATR/BPN No. 6/2018, new SNI standards) may address identified gaps.
5. Language and translation: Indonesian regulations were analysed in the original Bahasa Indonesia, with key provisions translated by the authors. Translation nuances may affect interpretation.

Despite these limitations, this study provides the first systematic, element-by-element benchmarking of Indonesian land parcel data quality regulations against ISO 19157 and international frameworks, offering a rigorous foundation for regulatory gap analysis and reform recommendations.

3. Results

3.1. Indonesian Regulatory Document Analysis

Table 2 presents a detailed analysis of Indonesian land registration regulations, mapping each regulation to the ten quality dimensions of our analytical framework. For each regulation-dimension pair, we identify specific provisions or note their absence.

Key Findings from Table 2:

1. Positional Accuracy: PMNA No. 3/1997 and the Technical Guidance of PTSL 2017 provide the most comprehensive coverage, specifying accuracy tiers with quantitative RMSE thresholds. This result represents partial alignment with ISO 19157 positional accuracy requirements, though testing procedures and reporting are not fully specified.
2. Completeness: Regulations emphasize document completeness (complete legal paperwork) but lack spatial completeness measures (omissions/commissions of parcel

features). The K1–K4 classification addresses registration completeness, not spatial data completeness.

3. Logical Consistency: PMNA No. 3/1997 requires valid parcel polygons and mentions “no overlaps,” but does not mandate automated topology validation or specify all sub-elements (conceptual, domain, format consistency).
4. Thematic Accuracy, Temporal Quality, Usability: These elements are largely absent from operational regulations. While SNI ISO 19157:2015 defines them comprehensively, the standard is not operationalized in ATR/BPN technical regulations.
5. Lineage: Regulations require archiving of source documents (GU, SU, surveyor certifications) but do not mandate structured lineage documentation (process steps, transformations, responsible parties) conforming to ISO 19157.
6. Metadata Integration: UU No. 4/2011 mandates metadata conforming to SNI ISO 19115, but ATR/BPN cadastral regulations do not require metadata for parcel datasets.
7. Conformance Testing and QA Documentation: These dimensions are absent from Indonesian regulations. No regulation mandates formal conformance testing of cadastral datasets against quality specifications, nor does it require structured quality assurance reports beyond surveyor certifications and administrative checklists.

3.2. Cross-Framework Comparison

Table 3 presents a comparative compliance scoring matrix at the framework level, scoring ISO 19157, INSPIRE, FGDC, ANZLIC, OGC, OSM, and Indonesian regulations across the ten quality dimensions using our four-level rubric (0 = None, 1 = Minimal, 2 = Partial, 3 = Full). The ‘Indonesia (ATR/BPN)’ column represents an aggregate score derived from the detailed regulation-by-regulation analysis in Table 2. For each quality dimension, the aggregate Indonesian score corresponds to the highest score achieved by any individual Indonesian regulation within that dimension, reflecting the best available regulatory provision within the national system.

The ‘Indonesia (ATR/BPN)’ column in Table 3 represents an aggregate score for the Indonesian regulatory framework, derived from the detailed regulation-by-regulation analysis presented in Table 2. For each quality dimension, the aggregate score corresponds to the highest score achieved by any individual Indonesian regulation within that dimension. This approach reflects the overall quality coverage available within the national regulatory system, regardless of which specific regulation provides that coverage. For example, if PMNA No. 3/1997 scores 2 (Partial) for Positional Accuracy while all other regulations score 1 or 0, the aggregate Indonesian score for Positional Accuracy is 2. This aggregation method enables meaningful cross-framework comparison by representing the best available regulatory provision for each quality dimension.

Key Findings from Table 3:

1. ISO 19157 and INSPIRE achieve perfect scores (30/30, 100%), reflecting their comprehensive, mandatory, and operationalized quality frameworks. INSPIRE’s explicit alignment with ISO 19157 and mandatory conformance testing for EU member states exemplify best-practice regulatory implementation.
2. ANZLIC (23/30, 77%) and FGDC (22/30, 73%) demonstrate strong alignment, particularly in positional accuracy, lineage, and metadata integration. However, both frameworks score lower on temporal quality, usability, and conformance testing, reflecting their origins as metadata standards rather than comprehensive quality assurance regimes.
3. OGC (20/30, 67%) scores moderately, as OGC standards provide interoperability mechanisms for quality metadata exchange but neither mandate quality assessment nor specify quality measures independently.

4. OSM (16/30, 53%) scores lowest among international frameworks, reflecting its community-driven, decentralized quality assurance model. OSM demonstrates partial coverage of completeness, logical consistency, positional accuracy, and thematic accuracy through intrinsic metrics and community validation, but lacks formal conformance testing and structured quality documentation.
5. Indonesia (11/30, 37%) scores significantly below all international frameworks, with critical gaps in temporal quality (score 1), usability (score 1), lineage (score 1), meta-data integration (score 1), conformance testing (score 0), and QA documentation (score 0). Indonesia's strongest dimension is positional accuracy (score 2) due to the KW classification system; however, even this is only partial due to the lack of mandatory testing and reporting. The gap between the formal adoption of SNI ISO 19157:2015 and its operational absence in ATR/BPN technical regulations reflects several institutional barriers: (i) the voluntary nature of SNI standards under Indonesian law (UU No. 20/2014, Article 18), which are not binding unless referenced in sector-specific regulations; (ii) institutional fragmentation between BSN, BIG, and ATR/BPN with limited coordination mechanisms for standard operationalization; (iii) the PTSL program's emphasis on registration completeness by 2025, which prioritized quantity over quality in operational planning and resource allocation; and (iv) limited technical capacity at the Kantah level to implement quality assessment procedures. Furthermore, the KW classification system (KW1–KW6), while representing Indonesia's most structured approach to data categorization, cannot serve as a comprehensive proxy for overall cadastral data quality, as it primarily assesses data integration completeness rather than multi-dimensional quality characteristics defined by ISO 19157.

3.3. Quantitative Compliance Assessment

Figures 3–5 visualize the quantitative compliance assessment, enabling rapid comparison of framework performance across quality dimensions and overall.

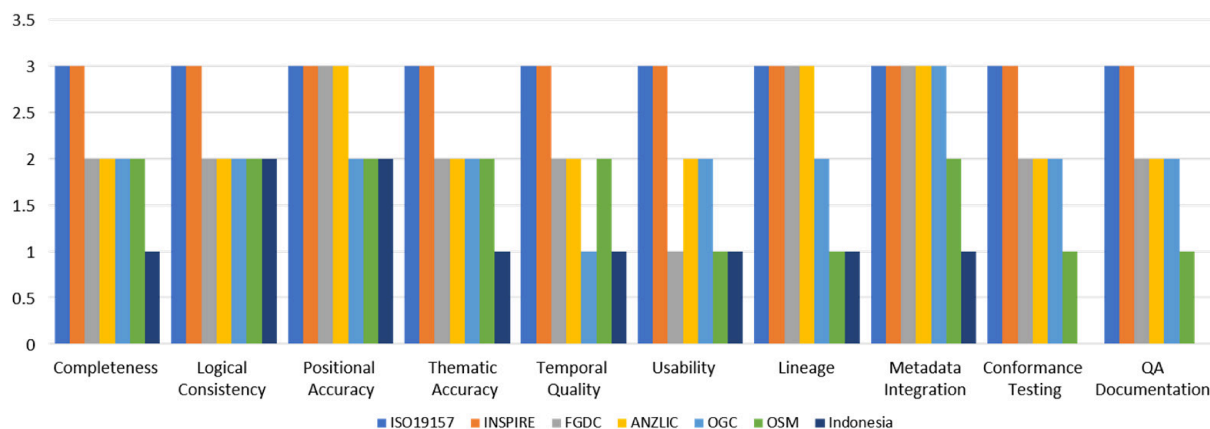


Figure 3. ISO 19157 Quality Element Coverage by Framework (Grouped Bar Chart). Indonesia (red bars) shows minimal coverage across most quality dimensions, with only partial coverage in Logical Consistency and Positional Accuracy. ISO 19157 and INSPIRE (dark blue bars) achieve full coverage across all dimensions.

Figure 3 presents a grouped bar chart comparing the seven frameworks across all ten quality dimensions. Each dimension is represented by a cluster of seven bars, with Indonesia highlighted in red. The visualization reveals stark contrasts: ISO 19157 and INSPIRE consistently achieve “Full” (score 3) coverage across all dimensions, appearing as uniform dark blue bars at the top of each cluster. FGDC and ANZLIC show strong performance across most dimensions, with most at “Partial” or “Full” levels (light blue and

purple bars). OGC and OSM exhibit more variable performance, with several dimensions at “Minimal” or “Partial” levels (cyan and green bars). Indonesia’s red bars are consistently at the bottom of each cluster, predominantly at “Minimal” (score 1) or “None” (score 0) levels, with only Logical Consistency and Positional Accuracy reaching “Partial” (score 2).

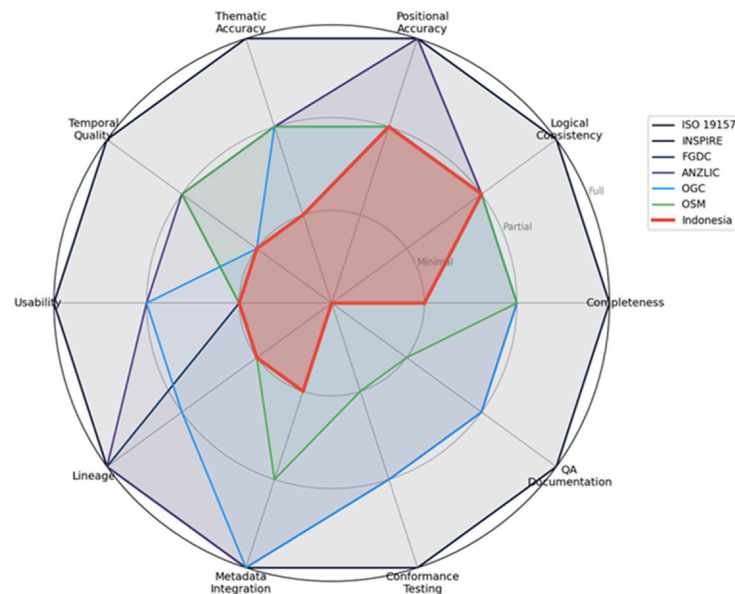


Figure 4. Radar Chart: ISO 19157 Quality Element Coverage by Framework. Indonesia’s coverage area (red polygon) is significantly smaller than all other frameworks, with zero coverage in Conformance Testing and QA Documentation. ISO 19157 and INSPIRE form perfect decagons (outermost polygons).

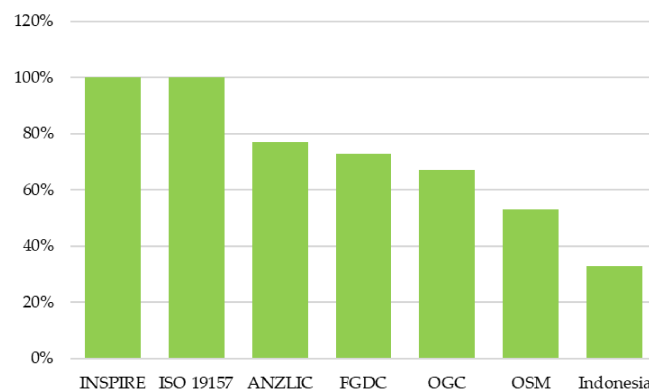


Figure 5. ISO 19157 Quality Element Compliance Score by Framework.

The chart visually confirms Indonesia’s critical gaps in Conformance Testing and QA Documentation (score 0, no visible red bar), and minimal coverage in Completeness, Thematic Accuracy, Temporal Quality, Usability, Lineage, and Metadata Integration (score 1, short red bars). This pattern underscores the hypothesis that Indonesian regulations lack comprehensive ISO 19157-compliant quality-assessment requirements.

Figure 4 presents a radar (spider) chart with 10 axes representing the quality dimensions, radiating from a central origin. Each framework is represented by a polygon connecting its scores on all dimensions. ISO 19157 and INSPIRE form perfect decagons at the outermost ring (score 3 on all axes), represented by overlapping dark blue and black polygons. FGDC and ANZLIC form large, relatively symmetric polygons (purple and light blue) with most vertices near the “Full” or “Partial” rings. OGC and OSM form smaller, more irregular polygons (cyan and green) with several vertices at “Minimal” levels. Indonesia’s polygon (red) is the smallest and most irregular, with vertices predomi-

nantly at “Minimal” levels and two vertices at the origin (Conformance Testing and QA Documentation, score 0), creating a collapsed shape.

The radar chart effectively communicates Indonesia’s comprehensive underperformance relative to international frameworks. The visual gap between Indonesia’s red polygon and the next-lowest framework (OSM, green) is substantial, underscoring the scale of regulatory reform needed to achieve international alignment.

Figure 5 presents a bar chart of overall compliance scores (as a percentage of the maximum possible score, 30 points) for each framework. ISO 19157 and INSPIRE achieve 100% (30/30 points, full-length dark blue bars). ANZLIC achieves 77% (23/30 points, purple bar), FGDC 73% (22/30 points, dark blue bar), OGC 67% (20/30 points, cyan bar), OSM 53% (16/30 points, green bar), and Indonesia 37% (11/30 points, red bar with red border).

The chart quantifies the magnitude of Indonesia’s regulatory gap: Indonesia scores 63 percentage points below ISO 19157/INSPIRE, 40 points below ANZLIC, 36 points below FGDC, 30 points below OGC, and 16 points below OSM. Indonesia’s 37% compliance indicates that more than three-fifths of ISO 19157 quality assurance principles are absent or minimally addressed in Indonesian land registration regulations.

This overall score validates the research hypothesis: Indonesian land registration regulations lack ISO 19157-compliant geospatial data quality assessment aspects, particularly in temporal quality, usability, lineage, conformance testing, and quality assurance documentation. The quantitative gap provides a clear baseline for measuring progress in future regulatory reforms.

4. Discussion

4.1. Interpretation of Findings

The results presented in Section 3 provide robust empirical evidence that Indonesian land parcel data quality regulations remain substantially misaligned with ISO 19157:2013 and broader international best practices. Indonesia’s overall compliance score of 37% (11/30 points) reflects systemic regulatory deficiencies across multiple quality dimensions, with particularly acute gaps concentrated in five interrelated elements: temporal quality, usability, lineage, conformance testing, and quality assurance documentation. These deficiencies are not isolated issues but collectively indicate a structural weakness in the regulatory framework, specifically in the domains of quality communication, accountability, and verification, core components that are fully operationalized in mature systems such as INSPIRE but remain underdeveloped in Indonesia despite the formal adoption of SNI ISO 19157:2015.

Temporal quality represents a foundational gap with significant operational consequences. ISO 19157 requires comprehensive documentation of temporal attributes, including data capture dates, update frequencies, version histories, and validity periods, which are essential in cadastral systems where land rights evolve continuously [48]. In contrast, Indonesian regulations limit temporal recording to basic administrative timestamps such as survey and registration dates (PP No. 24/1997; PMNA No. 3/1997), without defining measurable temporal quality indicators or reporting mechanisms [19,20]. As a result, users cannot reliably assess data currency, detect outdated parcels, or reconstruct the temporal evolution of land boundaries, an issue exacerbated by the PTSL program (2017–2025), which produced a large but temporally heterogeneous dataset lacking standardized temporal metadata [65].

A related deficiency lies in the absence of explicit usability (fitness-for-purpose) specifications and structured lineage documentation. ISO 19157 emphasizes that data usability is context-dependent and requires systematic evaluation through quality reports and user-

oriented metrics [1]. Yet Indonesian regulations implicitly assume uniform data quality across all parcels, despite the KW1 to KW6 classification system, which inherently reflects varying data reliability levels without linking them to specific use cases. Simultaneously, lineage, defined as the traceability of data sources, processing steps, and transformations, is only partially addressed through document archiving requirements, without structured documentation of workflows or processing histories. This limitation reduces transparency and makes it difficult to diagnose errors, trace inconsistencies, or establish evidentiary chains in legal disputes.

The most critical operational gaps, however, are the lack of conformance testing and structured quality assurance (QA) documentation. ISO 19157 mandates formal validation procedures, including automated testing, sampling strategies, and defined acceptance criteria. At the same time, frameworks such as INSPIRE require conformance testing before datasets are published [12,43,45]. Indonesian regulations lack such mechanisms, relying instead on surveyor certifications and administrative completeness checks, which do not guarantee spatial or attribute accuracy [5,7,50,57]. Furthermore, the absence of standardized QA documentation, such as quality reports, audit trails, and test records, undermines transparency, prevents systematic monitoring of quality trends, and diffuses accountability across institutions [12,18,39]. Collectively, these five interrelated gaps demonstrate that although Indonesia has formally adopted ISO 19157 (SNI ISO 19157:2015), its principles have not been translated into enforceable technical regulations governing the production of cadastral data, leaving a critical disconnect between normative standards and operational practice.

Illustrative Case: To ground our regulatory analysis in operational reality, we briefly illustrate how identified gaps translate into concrete problems at the land office level. Published quality assessments and ATR/BPN internal reports document several recurring issues: (i) **Overlapping parcels:** The absence of mandatory automated topology validation allows parcels with overlapping boundaries to enter the registration system. The Geo-KKP system provides topology checking tools, but their use is not mandated by regulation, and Kantah staff may bypass validation under workload pressure. (ii) **Boundary disputes:** Parcels registered through PTSL using lower-accuracy methods may have positional errors exceeding acceptable limits, leading to boundary conflicts when adjacent parcels are subsequently surveyed with higher precision. The absence of mandatory quality reporting means affected parties cannot verify the original measurement accuracy. (iii) **Data integration failures:** Approximately 57% of registered parcels historically fell into KW4–KW6 categories, indicating incomplete integration between spatial and textual records—a direct consequence of inadequate quality assurance documentation requirements. These examples demonstrate that the regulatory gaps identified through our benchmarking analysis have tangible operational consequences affecting legal certainty and administrative efficiency.

4.2. PTSL Program and Quality Trade-Offs

The Complete Systematic Land Registration (PTSL) program, launched in 2017 to register all land parcels in Indonesia by 2025, represents a major national initiative to accelerate tenure security and formalize land rights. To achieve rapid coverage, PTSL emphasizes speed and scalability by adopting simplified procedures, lower-accuracy survey methods (such as handheld GPS and imagery interpretation), and streamlined documentation processes. This approach has delivered strong quantitative results, with more than 40 million parcels registered between 2017 and 2023; however, the focus on volume has come at the expense of systematic quality assurance.

The regulatory basis for PTSL, Permen ATR/BPN No. 6/2018, explicitly permits the use of lower-accuracy measurement techniques to accelerate field operations and

does not require formal testing of positional accuracy, data completeness, or topological consistency [19]. While this flexibility supports rapid implementation, it has also led to a significant proportion of parcels being classified as KW5 and KW6, indicating relatively low positional accuracy ($RMSE > 3$ m), which may not be sufficient for applications such as urban planning, infrastructure design, or legal dispute resolution. Empirical assessments further reveal common data quality issues, including overlapping parcels, gaps, incomplete attributes, and inconsistencies with existing cadastral maps.

More broadly, the PTSL program highlights a fundamental trade-off in land administration systems between achieving wide coverage and ensuring high data quality. The “fit-for-purpose” land administration approach, promoted by organizations such as FIG and the World Bank, supports the idea that faster, lower-accuracy initial registration is acceptable, provided that data quality can be improved progressively over time [10]. However, this approach depends on clear documentation of initial data quality, defined improvement pathways, and transparency about data limitations for end users.

In the Indonesian context, these supporting conditions are not yet fully in place. The absence of temporal-quality metadata, usability guidelines, and structured quality documentation means users often lack the information needed to assess whether cadastral data are suitable for specific purposes. As a result, while PTSL has been successful in expanding land registration coverage, it has also introduced challenges related to data reliability and long-term usability that require further regulatory and technical refinement.

The metadata implementation gap exemplifies the broader challenge of inter-institutional coordination in Indonesian geospatial governance. Although Article 13 of UU No. 4/2011 mandates that all geospatial information producers comply with national metadata standards (based on SNI ISO 19115), ATR/BPN cadastral datasets remain largely devoid of standardized metadata. This gap arises because UU No. 4/2011 designates BIG—not ATR/BPN—as the coordinating authority for metadata standards, creating an institutional disconnect where ATR/BPN does not perceive metadata production as its operational responsibility. Furthermore, ATR/BPN’s land information systems (Geo-KKP and KKP-Web) were architected for land registration transactions and lack built-in metadata generation capabilities conforming to ISO 19115. The national geoportal (Ina-Geoportal), administered by BIG, has not been integrated with ATR/BPN’s systems, preventing automated metadata harvesting. At the operational level, Kantah staff lack training in metadata standards and face competing priorities that deprioritize metadata documentation. Finally, no monitoring or enforcement mechanism exists to verify compliance with Article 13, rendering the metadata mandate effectively unenforceable.

4.3. SNI ISO 19157:2015 Adoption vs. Operationalization Gap

Indonesia’s formal adoption of ISO 19157:2013 as a national standard (SNI ISO 19157:2015) through the National Standardization Agency (BSN) represents a policy commitment to international quality standards. SNI ISO 19157:2015 is a direct translation of ISO 19157:2013, retaining all seven quality elements, sub-elements, quality measures, and evaluation procedures. However, adoption of a voluntary standard does not automatically translate into operational implementation in government regulations and production workflows.

Our analysis reveals a substantial operationalization gap: while SNI ISO 19157:2015 comprehensively defines all quality elements, ATR/BPN technical regulations (PMNA No. 3/1997, Permen ATR/BPN No. 6/2018, Technical guidance of PTSL 2017) do not reference SNI ISO 19157:2015 or operationalize its provisions into mandatory quality specifications, evaluation procedures, and reporting requirements for cadastral data [50]. This gap is evident in Table 1: SNI ISO 19157:2015 scores “Full” across all quality dimensions, while

operational ATR/BPN regulations score “Minimal” or “Partial” on most dimensions and “None” on conformance testing and QA documentation.

The operationalization gap reflects several institutional challenges: (1) SNI standards are voluntary unless explicitly referenced in regulations, and ATR/BPN has not issued regulations mandating SNI ISO 19157:2015 compliance for cadastral data; (2) operationalizing ISO 19157 requires developing detailed technical specifications (e.g., sampling protocols, acceptance thresholds, validation algorithms) tailored to Indonesian cadastral contexts, which requires technical expertise and inter-agency coordination between BSN, BIG, and ATR/BPN; (3) implementing ISO 19157-compliant quality assurance requires investments in training, software tools, and quality control personnel, which compete with PTSL’s coverage priorities for limited resources; (4) there is limited awareness of ISO 19157 among field surveyors and Kantah staff, who are more familiar with traditional quality control practices (surveyor certifications, administrative checklists) than with structured quality assessment frameworks.

Bridging the operationalization gap requires: (1) issuing a new ATR/BPN ministerial regulation explicitly mandating SNI ISO 19157:2015 compliance for all cadastral datasets, with phased implementation timelines; (2) developing technical guidelines operationalizing ISO 19157 elements into cadastral-specific quality specifications, including quantitative thresholds, sampling protocols, and validation procedures; (3) integrating ISO 19157-compliant quality checks into cadastral production software (e.g., automated topology validation, attribute domain checks, metadata generation); (4) conducting training programs for surveyors and Kantah staff on ISO 19157 principles and quality assessment methods; (5) establishing a national quality monitoring system, aggregating quality reports from Kantah to track quality trends and identify systemic deficiencies.

While the KW classification system (KW1–KW6) represents Indonesia’s most structured approach to cadastral data categorization, our analysis reveals that it cannot serve as a comprehensive proxy for overall cadastral data quality. The KW system primarily assesses data integration completeness—specifically, the presence and linkage of mapped parcels, spatial and textual survey documents, and land books—rather than the multi-dimensional quality characteristics defined by ISO 19157. Critical quality dimensions including temporal quality (currency and validity of temporal attributes), usability (fitness for specific applications), lineage (documentation of data provenance and transformation history), thematic accuracy (correctness of attribute classifications), and metadata conformance remain entirely outside the scope of the KW framework. Consequently, a parcel classified as KW1 (highest quality under the current system) may still exhibit significant deficiencies in temporal currency, lack standardized metadata, or contain undocumented lineage gaps. We recommend that ATR/BPN develop an expanded, multi-dimensional quality classification framework that incorporates all seven ISO 19157 quality elements, moving beyond the current integration-focused KW system toward a holistic quality assessment model.

4.4. Comparison with INSPIRE Success Factors

INSPIRE’s achievement of 100% ISO 19157 compliance (Table 3, and Figure 3) reflects several success factors that offer lessons for Indonesian regulatory reform:

1. **Legal Mandate for Quality Assurance**
INSPIRE Directive 2007/2/EC is legally binding on EU member states, mandating that spatial datasets conform to common data specifications and quality requirements. Member states face legal consequences for non-compliance, creating strong institutional incentives for quality assurance. In contrast, Indonesian quality standards (SNI ISO 19157:2015, UU No. 4/2011) are either voluntary or lack detailed implementing regulations, resulting in weak enforcement.

2. **Detailed Data Specifications**
INSPIRE provides theme-specific data specifications, including the Data Specification on Cadastral Parcels (D2.8.I.6), which operationalize ISO 19157 elements into cadastral-specific quality requirements, including quantitative thresholds, validation rules, and metadata schemas. These specifications eliminate ambiguity and provide clear guidance for data producers. Indonesia lacks analogous cadastral-specific quality specifications operationalizing SNI ISO 19157:2015.
3. **Mandatory Conformance Testing**
INSPIRE requires that all datasets undergo conformance testing against data specifications before publication, using automated validation services (e.g., INSPIRE Validator) that check geometry validity, attribute domains, metadata completeness, and quality metadata. Conformance testing results are published in metadata, enabling users to assess fitness-for-purpose. Indonesia does not mandate conformance testing for cadastral datasets.
4. **Quality Metadata and Reporting**
INSPIRE mandates that all datasets include ISO 19115/19139-compliant metadata documenting quality for all seven ISO 19157 elements, with structured quality reports published in national and European metadata catalogs. This transparency enables users to discover, assess, and select datasets based on fitness-for-purpose. Indonesia mandates metadata in principle (UU No. 4/2011) but does not enforce metadata publication for cadastral datasets.
5. **Institutional Coordination and Capacity Building**
INSPIRE implementation involved extensive coordination among EU institutions, member states, and thematic working groups, supported by technical guidelines, training programs, and validation tools. The European Commission provided funding and technical assistance to support member state compliance. Indonesia's quality assurance efforts are fragmented across BSN (standards development), BIG (geospatial coordination), and ATR/BPN (cadastral production), with limited inter-agency coordination and capacity building.

Indonesia should do the following to replicate the success of INSPIRE: (1) move the quality assurance process for voluntary standards to legally binding standards in the ATR/BPN regulations; (2) create the cadastral data specification documents that implement the ISO 19157 elements, using INSPIRE as a foundation; (3) require all cadastral datasets to undergo conformance testing, and develop or modify automated validation tools; (4) require all cadastral datasets to be validated for the publication of metadata, and devolve quality metadata to the national geoportal; (5) establish the working groups BSN-BIG-ATR/BPN, and strengthen the interagency collaboration and quality assurance training.

We recommend establishing a mandatory conformance testing stage (*pengesahan kualitas*) within the land registration workflow, positioned between field survey completion and legal registration (*pengesahan*). This quality gate would require that all parcel datasets pass automated conformance tests before receiving legal registration status. The proposed testing protocol would include: (a) topology validation ensuring non-overlapping, closed polygon boundaries with correct node connectivity; (b) coordinate accuracy verification through comparison with control points or independent measurements, with rejection of parcels exceeding maximum permissible positional errors defined by land class; (c) attribute completeness checking against a mandatory field registry; and (d) metadata conformance testing against SNI ISO 19115 requirements. These tests should be integrated into the Geo-KKP platform as automated validation modules, reducing reliance on subjective expert judgment and enabling consistent, reproducible quality assessment across all *Kantah*. We

further recommend linking surveyor certification renewal to demonstrated compliance records, incentivizing quality-conscious fieldwork practices.

While INSPIRE's success demonstrates the effectiveness of legally binding quality mandates with transparent reporting mechanisms, direct implementation of this model in Indonesia requires consideration of distinct institutional, economic, and capacity constraints. Indonesia's decentralized administrative structure, limited local government budgets, shortage of trained geospatial professionals at the Kantah level, and the sheer scale of its cadastral inventory (126 million parcels across 34 provinces) present challenges fundamentally different from those faced by EU member states during INSPIRE implementation. Accordingly, we propose a graduated, three-tier implementation model: Tier 1 (Short-term, 0–1 year): Regulatory amendments to reference SNI ISO 19157:2015 in ministerial regulations, development of simplified coding protocols and quality checklists, and awareness-building workshops for Kantah managers. Tier 2 (Medium-term, 1–3 years): Development and deployment of automated validation tools within Geo-KKP, establishment of pilot quality assurance programs in selected provinces, training of quality assessment personnel, and creation of a national quality monitoring dashboard. Tier 3 (Long-term, 3–5 years): Full operationalization of ISO 19157 across all cadastral operations, institutional integration between BIG, BSN, and ATR/BPN for quality governance, comprehensive capacity building at all administrative levels, and mandatory conformance testing linked to legal registration. This graduated approach acknowledges that Indonesia cannot achieve INSPIRE-equivalent quality governance overnight but can make systematic, incremental progress toward international alignment.

4.5. Implications for Indonesian Land Administration Reform

As Indonesia approaches the 2025 completion target of the PTSL program, the findings indicate a necessary shift in focus from registration coverage to data quality consolidation. While PTSL has been highly effective in accelerating land registration, the absence of integrated quality assurance mechanisms suggests that post-registration strategies will play a critical role in determining the long-term reliability of cadastral data. The need for systematic quality audits, pathways for upgrading lower-quality parcels (e.g., KW5 and KW6), and the integration of quality controls into routine cadastral maintenance reflect an underlying transition from expansion to stabilization within the land administration system. This transition also highlights that data quality is not a one-time outcome, but a continuous process embedded within the lifecycle of cadastral management.

The analysis further reveals that regulatory gaps are not evenly distributed but concentrated in several high-impact quality dimensions that directly affect data usability and legal defensibility. In particular, the absence of conformance testing, structured quality assurance documentation, temporal quality controls, and lineage transparency indicates that the Indonesian framework lacks critical mechanisms for validating and communicating data quality. These dimensions form the backbone of mature land administration systems, and their limited operationalization in Indonesia suggests that the issue is not merely technical but systemic, affecting how data quality is defined, measured, and enforced in practice [62]. Consequently, the current regulatory structure provides only partial assurance of data reliability, especially in contexts requiring high precision and accountability.

In addition, the low level of metadata integration points to a broader limitation in the supporting infrastructure of cadastral data management. Without a comprehensive and standardized metadata system, users are constrained in their ability to evaluate data suitability, trace data origins, or understand the conditions under which data were produced. This lack of transparency reduces the practical usability of cadastral information, particularly for stakeholders such as planners, developers, and financial institutions who

rely on clear quality indicators for decision-making. The issue is therefore not only about data availability but also about data interpretability and trust.

Finally, the findings underscore that institutional capacity and external engagement are integral to the effectiveness of quality assurance systems. Variations in technical capability across local land offices (Kantah), combined with the absence of standardized procedures and specialized roles, lead to inconsistent data quality management. At the same time, the comparison with international frameworks suggests that Indonesia's current position reflects a gap in both technical implementation and institutional learning. In this context, global and regional cooperation can be understood not simply as an option but as part of the broader ecosystem through which standards, practices, and innovations in land administration evolve [10].

Post-PTSL Quality Upgrade Strategy. Following the anticipated completion of the PTSL registration program, ATR/BPN must transition from a quantity-focused to a quality-focused operational paradigm. We propose the following mechanisms for systematically upgrading parcels currently classified as KW5 and KW6: (i) **Risk-Based Prioritization:** Parcels in high-value urban areas, economic development zones, and areas with historical boundary disputes should be prioritized for quality upgrading, using spatial analytics to identify clusters of low-quality parcels requiring immediate attention. (ii) **Automated Quality Validation:** Integration of topology validation, attribute completeness checks, and coordinate accuracy testing into the Geo-KKP and KKP-Web platforms, enabling real-time quality monitoring and flagging of parcels requiring remediation. (iii) **Phased Re-Survey Campaigns:** Deployment of modern GNSS and UAV-based survey technologies for re-measurement of parcels with insufficient positional accuracy, beginning with priority areas identified under the risk-based framework. (iv) **Quality Monitoring Dashboards:** Establishment of centralized quality indicators for each Kantah, enabling ATR/BPN to track progress, allocate resources, and identify persistent quality gaps at the institutional level. (v) **Regulatory Quality Thresholds:** Amendment of land registration regulations to mandate minimum quality standards (aligned with ISO 19157) for parcels entering the formal registration stage, preventing future registration of parcels below acceptable quality levels.

A critical challenge facing ATR/BPN is the upgrading of legacy cadastral data—parcels registered prior to or during the PTSL program under less stringent quality requirements. As of the latest available data, a significant proportion of registered parcels remain classified at KW4–KW6 levels, indicating incomplete data integration, potential positional inaccuracies, or missing documentation. We propose the following strategies for legacy data quality improvement: (i) **Quality Triage:** Systematic classification of legacy parcels by quality deficiency type (positional accuracy, integration completeness, missing documentation) to enable targeted remediation rather than blanket re-survey. (ii) **Progressive Migration:** Establishment of minimum quality thresholds that legacy parcels must meet within defined timeframes (e.g., all parcels to achieve minimum KW3 within 5 years), with regulatory mandates preventing re-certification or transaction processing for parcels below threshold. (iii) **Opportunistic Upgrading:** Leveraging routine land transactions (transfers, subdivisions, mortgages) as triggers for mandatory quality verification and upgrading of affected parcels, spreading remediation costs across transaction events. (iv) **Technology-Enabled Mass Upgrading:** Deployment of satellite imagery, LiDAR, and automated feature extraction for cost-effective mass positional verification of legacy parcels without requiring individual field surveys.

4.6. Recommendations for Regulatory Improvement

Based on the findings and discussion, five key recommendations can be formulated to guide regulatory and institutional reform toward achieving ISO 19157 compliance in cadastral systems. These recommendations are organized in Table 4 as a phased implementation framework to provide actionable, time-bound guidance: Short-term (Year 1) actions focus on regulatory amendments and awareness building; Medium-term (Years 2–3) actions target automated tool deployment and pilot programs; Long-term (Years 4–5) actions address full system integration and sustained quality governance. Where applicable, comparisons with INSPIRE best practices are drawn to illustrate transferable principles.

Table 4. Phased Implementation Timeline for Regulatory Reform Recommendations.

Phase	Timeline	Key Actions	Expected Outcome
Short-term (Phase 1)	Year 1	- Formally adopt SNI ISO 19157:2015 into ATR/BPN operational workflow via Ministerial Decree - Develop detailed data quality specifications for KW classification aligned to all six ISO quality dimensions - Conduct pilot inter-rater reliability training for field surveyors in three provinces	SNI ISO 19157:2015 legally binding for land data collection; baseline quality specifications established
Medium-term (Phase 2)	Years 2–3	- Deploy automated validation tools (conformance testing) integrated with the Geo-KKP system - Establish a national cadastral metadata registry covering all six ISO quality dimensions - Launch capacity-building program for survey and mapping officers on quality standards	Automated quality checking operational; metadata infrastructure in place; workforce competency in quality assurance improved
Long-term (Phase 3)	Years 4–5	- Implement systematic KW5/KW6 legacy parcel upgrade programme with phased re-survey - Establish continuous quality monitoring mechanism with annual compliance reporting to the Ministry - Share benchmarking methodology with ASEAN partner countries through regional cadastral cooperation	Comprehensive quality management institutionalized; legacy data gaps addressed; regional knowledge transfer achieved

1. First, a comprehensive regulatory framework for quality assurance of cadastral geospatial data is needed. Such a framework should formally mandate alignment with ISO 19157 (or its national equivalent) by referencing the standard in ministerial regulations, moving beyond voluntary adoption. Short-term action: Amend Permen ATR/BPN No. 6/2018 to mandatorily reference SNI ISO 19157:2015 and issue a Director General circular mandating quality checklists for all new registrations.
2. Second, countries should develop detailed cadastral data quality specifications that contextualize ISO 19157 elements into practical, domain-specific standards. These specifications should define measurable thresholds for completeness, logical consistency, positional accuracy, thematic accuracy, temporal quality, usability, and lineage, alongside clear evaluation procedures, validation protocols, and metadata schemas. Providing technical guidelines, worked examples, and validation checklists is essential to ensure consistent implementation across institutions and jurisdictions. In the Indonesian context, this requires revising Pasal 22 ayat (3) PP No. 24/1997, which currently grants the Minister authority to determine only the ‘form, content, method of filling, storage and maintenance of surat ukur (measurement certificates)’, to explicitly include mandatory quality metadata elements: positional accuracy class (KW), measurement date, survey method, equipment type, and accuracy validation results. Similarly, Pasal 16 ayat (5), which delegates the technical standards for titik dasar

teknik (geodetic control points) and peta dasar pendaftaran (base registration maps) to the Minister, should be updated to require ISO 19115-compliant metadata for all base maps used in cadastral registration.

3. Third, the institutionalization of conformance testing and the deployment of validation tools are critical for ensuring data reliability. This includes mandating pre-registration validation of spatial data through automated tools integrated into the cadastral workflow. Medium-term action: Deploy automated topology validation and attribute completeness checking in Geo-KKP; pilot pre-registration conformance testing (pengesahan kualitas) in selected provinces before national rollout.
4. Fourth, the development of a national or interoperable cadastral metadata infrastructure is essential to enhance transparency and usability. This involves creating centralized metadata catalogs with quality metadata conforming to SNI ISO 19115, enabling users to assess fitness-for-purpose. Long-term action: Full integration of ATR/BPN metadata with the national geoportal (Ina-Geoportal) per UU No. 4/2011 requirements, with automated metadata harvesting from Geo-KKP and KKP-Web systems.
5. Finally, strengthening institutional capacity and implementing continuous quality monitoring mechanisms are fundamental to sustaining quality assurance practices. This includes systematic training of Kantah personnel in quality assessment methods, establishment of quality monitoring dashboards with performance indicators for each land office, and a periodic national cadastral quality audit program. Short-to-medium term action: Develop coding protocols and training modules (Year 1), followed by provincial-level quality monitoring dashboards and systematic capacity building programs (Years 2–3). Additionally, strategies for upgrading legacy parcels (KW5/KW6) should be developed through risk-based prioritization, opportunistic upgrading during routine land transactions, and technology-enabled mass verification [18].

Our regulatory gap analysis provides the essential prerequisite foundation for subsequent empirical research. By establishing a systematic baseline of what Indonesian regulations require regarding data quality, this study enables future researchers to design targeted empirical assessments that measure actual quality performance against regulatory expectations—determining not only whether quality is inadequate, but specifically which regulatory requirements are being met or violated in practice.

4.7. Regulatory Analysis Versus Field Practice: Limitations and Future Directions

It is important to acknowledge that this study's findings are based on regulatory document analysis rather than direct empirical assessment of cadastral measurement practices in the field. is significant where regulations establish minimum standards and procedural requirements, but actual field practices may diverge substantially from what is formally prescribed, in either direction. On one hand, field surveyors and local land offices (Kantah) may apply informal quality checks, local institutional knowledge, and experienced judgment that exceed the minimum regulatory requirements, particularly in well-resourced urban offices with experienced staff and modern equipment. On the other hand, resource constraints, workload pressures from PTSL coverage targets, limited technical capacity in rural Kantah, and the absence of enforceable quality benchmarks suggest that actual field practice may, in many cases, fall below even the minimal standards identified in the regulatory analysis. Empirical evidence from quality assessments of PTSL-registered parcels, showing widespread KW5 and KW6 classifications, overlapping boundaries, and incomplete attributes, supports the latter scenario as the more prevalent reality in large-scale registration contexts. Consequently, the 37% regulatory compliance score reported in this study likely represents an upper bound of actual data quality assurance in practice, and the true gap between Indonesian cadastral data quality and ISO 19157 requirements

may be even wider than the regulatory analysis suggests. Future research should therefore complement this regulatory analysis with systematic empirical quality assessments, applying ISO 19157 evaluation procedures directly to cadastral datasets across diverse regions, land categories, and Kantah offices, to quantify the gap between regulatory intent and operational reality. Such studies would provide an evidence base for targeted capacity-building interventions and validate whether proposed regulatory reforms translate into measurable improvements in field data quality.

4.8. Future Research Directions

This study employs a regulatory gap analysis based on document review and scoring; however, further research is required to strengthen and validate these findings through empirical and comparative approaches.

First, future studies should undertake systematic empirical assessments of cadastral data quality by applying ISO 19157 evaluation procedures to datasets across different regions and land categories. Such analysis would enable direct comparison between observed data quality and existing regulatory standards, thereby revealing implementation gaps in practice. Complementing this, comparative case studies across local land administration offices or equivalent institutions are needed to examine variations in quality assurance practices, including workflows, tools, human resources, and resulting data quality outcomes, to identify both best practices and structural constraints.

In addition, economic and user-oriented perspectives should be incorporated to better inform policy and investment decisions. Cost-benefit analyses can quantify the trade-offs associated with implementing ISO 19157-compliant quality assurance systems, balancing investments in tools, training, and personnel against benefits such as reduced disputes, improved market efficiency, and lower long-term correction costs. At the same time, user needs assessments involving key stakeholders, such as planners, developers, financial institutions, and legal professionals, are essential to understand fitness-for-purpose requirements and to align data quality standards with actual use cases and willingness to pay.

From a technical perspective, future research should also focus on developing and testing automated validation tools tailored to cadastral systems. These may include topology validation, positional accuracy assessment, and metadata generation tools, which should be piloted and evaluated in operational environments to assess their usability, scalability, and impact on data quality outcomes. Furthermore, longitudinal studies are needed to track how cadastral data quality evolves, particularly in large-scale registration programs, to understand whether quality improves, stabilizes, or deteriorates, and to identify the institutional and technical factors influencing these trends.

Expanding the analytical scope to cross-national comparisons would provide valuable insights into how different countries address cadastral data quality within their regulatory frameworks. Benchmarking across regions, particularly among countries with similar land administration challenges, can help identify transferable best practices, reveal common gaps, and support efforts to harmonize cadastral quality standards at regional or international levels.

5. Conclusions

This study presents the first systematic regulatory gap analysis benchmarking Indonesian land parcel data quality regulations against ISO 19157:2013 and five international geospatial quality frameworks. Through a mixed-methods approach combining qualitative document analysis with a quantitative scoring rubric validated by inter-rater reliability assessment (Fleiss' Kappa = 0.78–0.82), we demonstrate that the Indonesian regulatory

framework achieves only 37% overall compliance (11/30 points) with ISO 19157 quality dimensions, significantly below all international benchmarks examined. Critical regulatory gaps in temporal quality, usability, lineage, metadata integration, conformance testing, and quality assurance documentation reflect institutional barriers including the voluntary nature of national standards, inter-agency fragmentation, and the prioritization of registration quantity over quality during the PTSL program.

Our phased implementation roadmap provides actionable guidance for regulatory reform, proposing a graduated three-tier approach that acknowledges Indonesia's institutional and economic constraints while establishing a clear trajectory toward international alignment. The proposed reforms—including mandatory SNI ISO 19157:2015 referencing in ministerial regulations, automated conformance testing, metadata integration, and capacity building—would position Indonesia's land administration system to deliver cadastral data of demonstrable fitness-for-purpose, supporting legal certainty, economic development, and sustainable land governance.

This study contributes a replicable benchmarking methodology applicable to other developing countries facing similar challenges in operationalizing international quality standards within resource-constrained, rapidly evolving land administration systems. Future research should complement this regulatory baseline with empirical cadastral data quality assessments, expert elicitation studies, cost-benefit analyses of quality assurance investments, and longitudinal monitoring of quality evolution as reform measures are implemented.

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Abbreviations

The following abbreviations are used in this manuscript:

ANZLIC	Australia and New Zealand Land Information Council
ATR/BPN	Kementerian Agraria dan Tata Ruang/Badan Pertanahan Nasional
ASEAN	Association of South East Asian Nations
BIG	Badan Informasi Geospasial/Geospatial Information Agency
BSN	Badan Standarisasi Nasional/National Standardization Agency

CEP	Circular Error Probable
CSDGM	Content Standard for Digital Geospatial Metadata
FGDC	Federal Geographic Data Committee
FIG	The International Federation of Surveyors
GPS	Global Positioning System
GU	Gambar Ukur/measurement sketch
ISO	International Standard Organization
Kantah	Kantor Pertanahan
KW	Kualitas (refer to the quality level of land records)
LADM	The Land Administration Domain Model
OGC	Open Geospatial Consortium
OSM	OpenStreetMap
RMSE	Root Mean Square Error
Permen	Peraturan Menteri Agraria dan Tata Ruang/Kepala Badan Pertanahan Nasional
PMNA	Peraturan Menteri Negara Agraria/National Agrarian Minister Regulation
PP	Peraturan Pemerintah
PTSL	Pendaftaran Tanah Sistematis Lengkap/Complete Systematic Land Registration
RRR	Rights–restrictions–responsibilities
SOP	Standard operating procedures
SNI	Standar Nasional Indonesia
SU	Surat Ukur/Measurement certificate
UU	Undang-undang
VGI	Volunteered Geographic Information

References

- Williamson, I.; Enemark, J.; Wallace, S.; Rajabifard, A. *Land Administration for Sustainable Development A New Book by Land Administration for Sustainable Development*; ESRI Press Academic: Redlands, CA, USA, 2010.
- Bennett, R.; Rajabifard, A.; Kalantari, M.; Wallace, J.; Williamson, I. Cadastral Futures: Building a New Vision for the Nature and Role of Cadastres. In *Proceedings of the FIG Working Week 2012, Rome, Italy, 6–10 May 2012*.
- The International Federation of Surveyors (FIG). *Statement on the Cadastre*; FIG: Copenhagen, Denmark, 1995.
- Kalantari, M.; Rajabifard, A.; Wallace, J.; Williamson, I. Spatially Referenced Legal Property Objects. *Land Use Policy* **2008**, *25*, 173–183. [\[CrossRef\]](#)
- Hanus, P.; Pęska-Siwik, A.; Benduch, P.; Szewczyk, R. Comprehensive Assessment of the Quality of Spatial Data in Records of Parcel Boundaries. *Measurement* **2020**, *158*, 107665. [\[CrossRef\]](#)
- Jansone, A.; Paršova, V. Evaluation of Vector Data Quality of Cadastral Map in Latvia. In *Proceedings of the International Scientific Conference Rural Development*; Vytautas Magnus University Agriculture Academy: Kaunas, Lithuania, 2010; pp. 95–100.
- Filho, A.G.G.; Borba, P.; Silva, V.H.S.; Feitosa, F.; Feitosa, R.Q. Quality Control Relevance on Acquisition of Large-Scale Geospatial Data to Urban Territorial Management. In *Proceedings of the IEEE Latin American GRSS & ISPRS Remote Sensing Conference (LAGIRS)*, Santiago, Chile, 21–26 March 2020.
- Devillers, R.; Bédard, Y.; Jeansoulin, R.; Moulin, B. Towards Spatial Data Quality Information Analysis Tools for Experts Assessing the Fitness for Use of Spatial Data. *Int. J. Geogr. Inf. Sci.* **2007**, *21*, 261–282. [\[CrossRef\]](#)
- Bank, W. *Doing Business 2020: Comparing Business Regulation in 190 Economies*; World Bank: Washington, DC, USA, 2020.
- Enemark, S.; McLaren, R.; Lemmen, C. Fit-for-Purpose Land Administration—Providing Secure Land Rights at Scale. *Land* **2021**, *10*, 972. [\[CrossRef\]](#)
- ISO 19157 2013; Data Quality. International Organization for Standardization: Geneva, Switzerland, 2013.
- European Parliament and Council. Directive 2007/2/EC of the European Parliament and of the Council of 14 March 2007 Establishing an Infrastructure for Spatial Information in the European Community (INSPIRE). *Off. J. Eur. Union* **2007**, *108*, 1–14. [\[CrossRef\]](#)
- Federal Geographic Data Committee (FGDC). *Content Standard for Digital Geospatial Metadata (CSDGM), Version 2*; FGDC-STD-001-1998; Federal Geographic Data Committee (FGDC): Reston, VA, USA, 1998.
- ISO 19115:2005; ANZLIC—The Spatial Information Council ANZLIC Metadata Profile: An Australian/New Zealand Profile of AS/NZ, Version 2.0 2015. International Standardization Organization: Geneva, Switzerland, 2015.
- Open Geospatial Consortium (OGC). *OGC Web Feature Service (WFS) Implementation Specification, Version 2.0, OGC 09-025r2 2010*; Open Geospatial Consortium (OGC): Arlington, VA, USA.

16. Goodchild, M.F. Citizens as Sensors: The World of Volunteered Geography. *GeoJournal* **2007**, *69*, 211–221. [[CrossRef](#)]
17. Ureña-Cámara, M.A.; Nogueras-Iso, J.; Lacasta, J.; Ariza-López, F.J. A Method for Checking the Quality of Geographic Metadata Based on ISO 19157. *Int. J. Geogr. Inf. Sci.* **2019**, *33*, 1–27. [[CrossRef](#)]
18. Wagner, M.; Henzen, C. Quality Assurance for Spatial Research Data. *ISPRS Int. J. Geoinf.* **2022**, *11*, 334. [[CrossRef](#)]
19. Psomadaki, S.; Dimopoulou, E.; van Oosterom, P.; Lemmen, C.; Fradelos, P. Model Driven Architecture Engineered Land Administration in Conformance with International Standards—Illustrated with the Hellenic Cadastre. *Land Use Policy* **2019**, *89*, 104207. [[CrossRef](#)]
20. Alves, J.C.A.; Alonso, J.M.; Julião, R.P. Procedimentos de Avaliação e Gestão Da Qualidade de Dados Espaciais Na Realização de Cadastro Simplificado Da Propriedade. In Proceedings of the XIII Colóquio Ibérico de Geografia, Santiago de Compostela, Spain, 24–27 October 2012.
21. Jakobsson, A.; Giversen, J. *Guidelines for Best Practice in Cross-Boundary PM&E*; European Commission: Brussels, Belgium, 2007.
22. ISO 19115-1:2014; Geographic Information—Metadata—Part 1: Fundamentals. International Standardization Organization: Geneva, Switzerland, 2014.
23. ISO 19157-1:2023; Geographic Information—Data Quality—Part 1: General Requirements. International Organization for Standardization: Geneva, Switzerland, 2023.
24. Veregin, H. Data Quality Parameters. In *Geographical Information Systems*, 2nd ed.; Longley, P.A., Goodchild, M.F., Maguire, D.J., Eds.; John Wiley & Sons, Inc.: Toronto, ON, Canada, 1999; Volume 1, pp. 177–189.
25. ISO/TS 19138:2006; Geographic Information—Data Quality Measures. International Standardization Organization: Geneva, Switzerland, 2006.
26. Forghani, M.; Delavar, M. A Quality Study of the OpenStreetMap Dataset for Tehran. *ISPRS Int. J. Geoinf.* **2014**, *3*, 750–763. [[CrossRef](#)]
27. Turunen, A. Data Quality Assurance of 3D Building Features in Data Integration Processes. Available online: <https://aaltodoc.aalto.fi/items/bc2306f2-2973-4778-896c-26482aeedef4> (accessed on 14 July 2026).
28. Biljecki, F.; Ledoux, H.; Stoter, J. An Improved LOD Specification for 3D Building Models. *Comput. Environ. Urban Syst.* **2016**, *59*, 25–37. [[CrossRef](#)]
29. van Oosterom, P. Research and Development in Geo-Information Generalisation and Multiple Representation. *Comput. Environ. Urban Syst.* **2005**, *29*, 379–391. [[CrossRef](#)]
30. FGDC-STD-007 1998; Geospatial Positioning Accuracy Standards, Part 3: National Standard for Spatial Data Accuracy. Federal Geographic Data Committee (FGDC): Reston, VA, USA, 1998.
31. Congalton, R.G.; Green, K. *Assessing the Accuracy of Remotely Sensed Data: Principles and Practices*, 3rd ed.; CRC Press: Boca Raton, FL, USA, 2019.
32. The American Society for Photogrammetry and Remote Sensing (ASPRS). *ASPRS Positional Accuracy Standards for Digital Geospatial Data*; ASPRS: Bethesda, MD, USA, 2014.
33. ISO 19116:2019; Geographic Information—Positioning Services. International Standardization Organization: Geneva, Switzerland, 2019.
34. Fonte, C.; See, L.; Lesiv, M.; Bastin, L.; Fritz, S. Usability of VGI for Validation of Land Cover Maps. *Int. J. Geogr. Inf. Sci.* **2017**, *31*, 1269–1291. [[CrossRef](#)]
35. Foody, G.M. Thematic Map Comparison: Evaluating the Statistical Significance of Differences in Classification Accuracy. *Photogramm. Eng. Remote Sens.* **2004**, *70*, 627–633. [[CrossRef](#)]
36. Haklay, M. How Good Is Volunteered Geographical Information? A Comparative Study of OpenStreetMap and Ordnance Survey Datasets. *Environ. Plan. B Plan. Des.* **2010**, *37*, 682–703. [[CrossRef](#)]
37. Mooney, P.; Minghini, M. A Review of OpenStreetMap Data. In *Mapping and the Citizen Sensor*; Foody, G., Ed.; Ubiquity Press: London, UK, 2017; pp. 37–59.
38. Craglia, M.; Goodchild, M.F.; Annoni, A.; Camara, G.; Gould, M.; Kuhn, W.; Mark, D.; Masser, I.; Maguire, D.; Liang, S.; et al. Next-Generation Digital Earth. *Proc. Natl. Acad. Sci. USA* **2012**, *109*, 11106–11111. [[CrossRef](#)] [[PubMed](#)]
39. ISO 19131:2007; Geographic Information—Data Product Specifications. International Standardization Organization: Geneva, Switzerland, 2007.
40. Aditya, T.; Maria-Unger, E.; vd Berg, C.; Bennett, R.; Saers, P.; Syahid, H.L.; Erwan, D.; Wits, T.; Widjajanti, N.; Santosa, P.B.; et al. Participatory Land Administration in Indonesia: Quality and Usability Assessment. *Land* **2020**, *9*, 79. [[CrossRef](#)]
41. Yaman, B.; Thompson, K.; Fahey, F. LinkedDataOps: Quality Oriented End-to-End Geospatial Linked Data Production Governance. *ISPRS Int. J. Geoinf.* **2020**, *9*, 635. [[CrossRef](#)]
42. ISO/TS 19157-2:2016; Geographic Information—Data Quality—Part 2: XML Schema Implementation. International Standardization Organization: Geneva, Switzerland, 2016.
43. ISO 1957-1:2023; Geographic Information-Data Quality-Part 1: Fundamentals. International Standardization Organization: Geneva, Switzerland, 2013.

44. *Implementation Rules and Technical Guidelines*; Directive 2007/2/EC; European Commission INSPIRE: Ispra, Italy, 2010.
45. van Oosterom, P.; Lemmen, C.; Ingvarsson, T.; van der Molen, P.; Ploeger, H.; Quak, W.; Stoter, J.; Zevenbergen, J. The Core Cadastral Domain Model. *Comput. Environ. Urban Syst.* **2006**, *30*, 627–660. [\[CrossRef\]](#)
46. Kotsev, A.; Minghini, M.; Tomas, R.; Cetl, V.; Lutz, M. From Spatial Data Infrastructures to Data Spaces—A Technological Perspective on the Evolution of European SDIs. *ISPRS Int. J. Geoinf.* **2020**, *9*, 176. [\[CrossRef\]](#)
47. Kang, H.-K.; Li, K.-J. A Standard Indoor Spatial Data Model—OGC IndoorGML and Implementation Approaches. *ISPRS Int. J. Geoinf.* **2017**, *6*, 116. [\[CrossRef\]](#)
48. Fonte, C.C.; Antoniou, V.; Bastin, L.; Estima, J.; Arsanjani, J.J. Assessing VGI Data Quality. In *Mapping and the Citizen Sensor*; Ubiquity Press: London, UK, 2017; pp. 137–163.
49. Navratil, G.; Frank, A.U. VGI for Land Administration—A Quality Perspective. *ISPRS Int. J. Geoinf.* **2013**, *2*, 159–171. [\[CrossRef\]](#)
50. *ISO 19152:2012*; Geographic Information—Land Administration Domain Model (LADM). International Standardization Organization: Geneva, Switzerland, 2012.
51. Lemmen, C.; Van Oosterom, P.; Eisenhut, C.; Uitermark, H. The Modelling of Rights, Restrictions and Responsibilities (RRR) in the Land Administration Domain Model (LADM). In Proceedings of the FIG International Congress, Sydney, Australia, 11–16 April 2010.
52. Minister of Agrarian Affairs Peraturan Menteri Negara Agraria Nomor 3 Tahun 1997 Tentang Ketentuan Pelaksanaan Peraturan Pemerintah Nomor 24 Tahun 1997 Tentang Pendaftaran Tanah 1997. Available online: <https://jdih.atrbpn.go.id/peraturan/detail/3/peraturan-pemerintah-nomor-24-tahun-1997> (accessed on 14 July 2026).
53. Suranto; Djojomartono, P.N. Licensed Surveyor Role Analysis for Achieving Indonesia Complete Systematic Land Registration (PTSL) in 2024. *IOP Conf. Ser. Earth Environ. Sci.* **2023**, *1127*, 012037. [\[CrossRef\]](#)
54. Huda, N.; Hernandi, A.; Gumilar, I.; Meilano, I.; Cahyaningtyas, L.A. The Strategic Development of Quality Improvement Land Data Incrementally Using Integrated PESTEL and SWOT Analysis in Indonesia. *Land* **2024**, *13*, 1655. [\[CrossRef\]](#)
55. Alifian Asmaaysi Menteri ATR/BPN Lapor 121 Juta Bidang Tanah Terdaftar Lewat PTSL. Available online: <https://ekonomi.bisnis.com/read/20241207/47/1822408/menteri-atrbpn-lapor-121-juta-bidang-tanah-terdaftar-lewat-ptsl> (accessed on 22 April 2026).
56. Jahani Chehrehbargh, F.; Rajabifard, A.; Atazadeh, B.; Steudler, D. Current Challenges and Strategic Directions for Land Administration System Modernisation in Indonesia. *J. Spat. Sci.* **2024**, *69*, 1097–1129. [\[CrossRef\]](#)
57. Kusmiarto, K.; Aditya, T.; Djurdjani, D.; Subaryono, S. Digital Transformation of Land Services in Indonesia: A Readiness Assessment. *Land* **2021**, *10*, 120. [\[CrossRef\]](#)
58. Presiden Republik Indonesia. *Undang-Undang Nomor 4 Tahun 2011 Tentang Informasi Geospasial*; Government of the Republic of Indonesia: Jakarta, Indonesia, 2011.
59. Presiden Republik Indonesia. Peraturan Pemerintah Nomor 24 Tahun 1997 Tentang Pendaftaran 1997. Available online: <https://jdih.atrbpn.go.id/peraturan/detail/3/peraturan-pemerintah-nomor-24-tahun-1997> (accessed on 14 July 2026).
60. Menteri Agraria dan Tata Ruang/Kepala Badan Pertanahan Nasional. Peraturan Menteri ATR/BPN Nomor 6 Tahun 2018 Tentang Pendaftaran Tanah Sistematis Lengkap 2018. Available online: <https://jdih.atrbpn.go.id/peraturan/detail/910/peraturan-menteri-agraria-dan-tata-ruang-kepala-badan-pertanahan-nasional-nomor-6-tahun-2018> (accessed on 14 July 2026).
61. *SNI ISO 19157:2015*; Informasi Geografis—Kualitas Data. Badan Standardisasi Nasional (BSN): Jakarta, Indonesia, 2015.
62. Direktur Jenderal Infrastruktur Keagrariaan. Petunjuk Teknis Nomor 01/JUKNIS-300/I/2018 Tahun 2018 Tentang Pengukuran dan Pemetaan Bidang Tanah Sistematis Lengkap, 2018. Available online: <https://jdih.atrbpn.go.id/peraturan/detail/1135/petunjuk-teknis-nomor-01-juknis-300-i-2018-tahun-2018> (accessed on 14 July 2026).
63. Mustofa, F.C. Evaluation of Land Information System Development in The Ministry of Agrarian Affairs and Spatial Planning/National Land Agency. *Bhumi J. Agrar. Dan Pertanah.* **2020**, *6*, 158–171.
64. Ginanjar, P.S.; Sudarsono, B.; Sasmito, B. The Implementation Study of GeoKKP System for Land Certificate Production in Kendal Regency Land Office, Central Jawa Province. *J. Geod. Undip* **2014**, *3*, 53–68.
65. Sutaryono, M. Implementasi Pendaftaran Tanah Sistematis Lengkap (PTSL) Di Indonesia. *Bhumi J. Agrar. Dan Pertanah.* **2018**, *4*, 1–14.

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