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Geospatial Evidence and Remote Sensing in Maritime Boundary Delimitation: A Legal Review

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Abstract. Maritime boundary delimitation is not only a legal matter but also depends on the quality of the spatial information used to describe the coast and surrounding maritime areas. This article reviews how geospatial data and remote sensing can support maritime boundary delimitation, particularly in relation to the law of the sea. The review draws on scientific literature, international legal instruments, judicial materials, and technical studies concerning maritime baselines, coastlines, satellite imagery, geographic information systems, and boundary determination. The findings show that remote sensing is useful for observing coastal features and shoreline change, while geographic information systems help organize and analyze coordinates, coastlines, maritime zones, and other spatial information needed in boundary studies. However, a coastline derived from satellite imagery cannot automatically be treated as a legally recognized baseline. Its legal relevance depends on several factors, including applicable legal rules, official recognition, positional accuracy, tidal conditions, image resolution, and the time of data acquisition. The issue becomes more complex in areas affected by erosion, accretion, and sea-level rise, where the physical coastline may change over time. This review argues that geospatial technology should be used as supporting scientific evidence within a clear legal framework. Closer integration between maritime law, geodesy, geographic information systems, and remote sensing can strengthen the accuracy, transparency, and legal defensibility of maritime boundary governance.

Keywords: maritime boundary; law of the sea; remote sensing; geospatial evidence; coastline

Abstrak. Delimitasi batas maritim tidak hanya berkaitan dengan aspek hukum, tetapi juga sangat bergantung pada kualitas informasi spasial yang digunakan untuk menggambarkan kondisi pantai dan wilayah laut di sekitarnya. Artikel ini mengulas bagaimana data geospasial dan penginderaan jauh dapat mendukung proses delimitasi batas maritim, khususnya dalam perspektif hukum laut. Kajian dilakukan dengan menelaah literatur ilmiah, instrumen hukum internasional, materi yudisial, serta kajian teknis yang berkaitan dengan garis pangkal, garis pantai, citra satelit, sistem informasi geografis, dan penetapan batas maritim. Hasil kajian menunjukkan bahwa penginderaan jauh bermanfaat untuk mengamati fitur pesisir dan perubahan garis pantai, sedangkan sistem informasi geografis membantu mengelola serta menganalisis koordinat, garis pantai, zona maritim, dan informasi spasial lain yang diperlukan dalam kajian batas. Meskipun demikian, garis pantai yang diperoleh dari citra satelit tidak dapat langsung dianggap sebagai garis pangkal yang diakui secara hukum. Kedudukan hukumnya tetap bergantung pada ketentuan yang berlaku, pengakuan resmi, ketelitian posisi, kondisi pasang surut, resolusi citra, dan waktu perekaman data. Persoalan menjadi semakin kompleks pada wilayah yang mengalami erosi, akresi, dan kenaikan muka laut karena

kondisi garis pantai dapat berubah dari waktu ke waktu. Kajian ini menegaskan bahwa teknologi geospasial sebaiknya digunakan sebagai bukti ilmiah pendukung dalam kerangka hukum yang jelas. Integrasi yang lebih erat antara hukum laut, geodesi, sistem informasi geografis, dan penginderaan jauh dapat memperkuat akurasi, transparansi, dan kepastian hukum dalam tata kelola batas maritim.
Kata Kunci: batas maritim; hukum laut; penginderaan jauh; bukti geospasial; garis pantai

1. Introduction

Maritime boundaries define the spatial extent within which coastal States exercise sovereignty, sovereign rights, and jurisdiction over marine areas and resources. Their determination is therefore both a legal and a geographical process. Under the United Nations Convention on the Law of the Sea (UNCLOS), the location of the coast is fundamental to the construction of maritime zones. Article 5 establishes the normal baseline as the low-water line along the coast as shown on large-scale charts officially recognized by the coastal State (United Nations, 1982). From these baselines, the breadth of the territorial sea and other maritime zones is measured. Although the legal rules governing maritime entitlement and delimitation are established by international law, their practical application depends heavily on spatial information capable of representing coastal features, coordinates, distances, and geographic relationships with sufficient accuracy.

This connection between law and geography becomes particularly important because coastlines are not static features. Coastal erosion, sediment accumulation, tidal variation, storms, human intervention, and longer-term sea-level change can alter the physical position and form of the land–water interface. Satellite observations have demonstrated the scale of this variability. Using more than three decades of satellite imagery, Luijendijk et al. (2018) showed substantial patterns of erosion, accretion, and stability across sandy coastlines worldwide. Such changes have consequences beyond coastal geomorphology because the physical characteristics of the coast may also affect the spatial information used in determining maritime reference features. In legal scholarship, the relationship between geographical change and maritime zones has consequently received growing attention, particularly in debates concerning whether baselines should respond to physical changes in the coastline or remain stable in the interest of legal certainty (Anggadi, 2022; Wendebourg, 2023).

At the same time, developments in Earth observation have significantly expanded the availability of coastal geospatial information. Landsat and Sentinel satellite missions provide repeated observations that allow coastlines to be mapped over large areas and

across long periods. Automated and semi-automated approaches can now derive shoreline positions from multispectral imagery with a level of consistency that would have been difficult to achieve through conventional field surveys alone. Sánchez-García et al. (2020), for example, demonstrated a method for extracting shoreline positions from medium-resolution satellite imagery, while Pucino et al. (2022) assessed Sentinel-2-derived shorelines against synchronous UAV surveys. More recently, Pardo-Pascual et al. (2024) evaluated automatically extracted Sentinel-2 shorelines across different coastal environments. These developments show that satellite imagery is increasingly capable of providing useful spatial evidence for understanding where and how coastal features change.

However, a satellite-derived shoreline should not be treated as equivalent to a legally recognized maritime baseline without further consideration. Remote sensing records the physical characteristics visible to a sensor at a particular time, whereas the legal status of a baseline is determined by the applicable rules of the law of the sea and by State practice. The position obtained from satellite imagery may vary according to tidal stage, coastal morphology, spatial resolution, image acquisition time, atmospheric conditions, and the extraction method used. Validation studies have shown that the accuracy of satellite-derived shorelines differs between coastal settings and may decline in environments with greater tidal ranges or complex beach morphology (Pucino et al., 2022; Vos et al., 2023). The distinction is therefore important: remote sensing can provide evidence about the physical location and evolution of the coast, but it does not independently determine the legal status of the line from which maritime entitlements are measured.

Geospatial technologies nevertheless have an important role in maritime boundary work. Geographic information systems allow different types of information including coastline data, base points, coordinates, nautical charts, geodetic reference systems, and maritime zone limits to be combined and examined within a common spatial framework. In Indonesia, where maritime administration involves an extensive and geographically complex archipelago, previous studies have shown how cartometric and geospatial approaches are closely connected to boundary determination. Prayogo and Sukoco (2021), for instance, identified changes in the technical rules used for determining regional sea boundaries under successive Indonesian regulations, including changes relating to reference points and the use of cartometric methods.

Remote sensing studies conducted in Indonesian coastal areas have likewise demonstrated that Landsat imagery can be used to extract and evaluate coastline positions, although the results remain dependent on the characteristics of the imagery and the extraction technique applied (Prayogo, 2021). These examples illustrate how legal provisions and geospatial techniques increasingly meet in practical maritime governance.

The need to understand this relationship is becoming more pressing as climate-related sea-level rise adds another dimension to coastal change. Recent law-of-the-sea scholarship has examined the tension between changing physical coastlines and the need for stable maritime entitlements. Anggadi (2022) found that a number of States have adopted approaches intended to preserve greater stability in the implementation of maritime baselines, while Wendebourg (2023) discussed the continuing debate over the so-called ambulatory baseline approach. The International Law Commission's final report on sea-level rise in relation to international law further concluded in 2025 that UNCLOS does not impose a general obligation on States to update duly deposited baselines, geographical coordinates, or maritime-zone limits solely because of coastline changes resulting from climate-related sea-level rise (International Law Commission, 2025). Oral (2025) similarly observes a growing convergence in State positions toward preserving legally established baselines and maritime boundaries despite subsequent physical changes to coastlines. These developments make the distinction between a changing physical shoreline and a legally recognized maritime reference particularly significant.

Despite these advances, the relevant literature remains divided largely along disciplinary lines. Remote sensing and coastal studies concentrate primarily on detecting, extracting, and validating shoreline positions, including the technical uncertainty associated with satellite-derived observations (Pucino et al., 2022; Vos et al., 2023; Pardo-Pascual et al., 2024). Law-of-the-sea scholarship, by contrast, has focused more strongly on the legal character of baselines, State practice, maritime-zone stability, and the implications of sea-level rise (Anggadi, 2022; Wendebourg, 2023; Oral, 2025). Taken together, these bodies of literature suggest a need for closer examination of the point at which technical coastal information becomes relevant to legal decision-making. In particular, greater attention is required to the conditions under which

remote sensing and other geospatial information can support, clarify, or potentially complicate the identification of coastal features used in maritime boundary processes.

Accordingly, this article reviews the role of geospatial evidence and remote sensing in maritime boundary delimitation from a law-of-the-sea perspective. It examines the legal foundations of maritime baselines and delimitation, the contribution of satellite remote sensing and geographic information systems to coastline identification and spatial analysis, the technical limitations that affect the interpretation of satellite-derived coastal features, and the legal challenges created by dynamic coastlines. By bringing legal and geospatial literature into a single analytical framework, the review seeks to clarify the appropriate role of remote sensing as scientific evidence in maritime boundary governance while maintaining the distinction between physical observations of the coast and legally recognized maritime reference features.

2. Method

2.1 Review Design

This study employed a structured integrative literature review to examine the relationship between geospatial evidence, remote sensing, and maritime boundary delimitation. An integrative approach was considered appropriate because the issue extends across several fields that use different types of evidence, including the law of the sea, geodesy, geographic information systems, coastal studies, and satellite remote sensing. Rather than limiting the review to a single research design or type of empirical study, this approach allows legal materials, technical studies, and interdisciplinary research to be examined within a common analytical framework. The review process followed the general principles of transparency in literature identification, selection, evaluation, and synthesis described by Snyder (2019) and Torraco (2016).

The review focused on four related questions: how maritime baselines and boundaries are understood under the law of the sea; how remote sensing and geospatial technologies are used to identify and monitor coastal features; what technical limitations affect the interpretation of satellite-derived coastlines; and how geospatial information can contribute to maritime boundary analysis without replacing the legal process through which maritime limits are established.

2.2 Literature Search and Source Selection

The literature search was organized around combinations of legal and geospatial terms. The main search terms included *maritime boundary*, *maritime delimitation*, *maritime baseline*, *law of the sea*, *UNCLOS*, *low-water line*, *coastline*, *shoreline change*, *satellite-derived shoreline*, *remote sensing*, *GIS*, *geospatial evidence*, *sea-level rise*, and *maritime zones*. These terms were combined where necessary, for example, "remote sensing AND maritime boundary," "satellite-derived shoreline AND baseline," "sea-level rise AND maritime zones," and "geospatial data AND law of the sea."

Academic literature was identified through Google Scholar and direct searches of journal and publisher platforms. Priority was given to peer-reviewed journal articles published from 2016 to August 2026 in order to represent recent developments in remote sensing technology, coastline mapping, maritime law, and sea-level rise. Earlier publications were retained only when they provided an important conceptual, methodological, or legal foundation that could not reasonably be replaced by more recent literature.

Because maritime boundary delimitation is governed not only by academic literature but also by international law, the review also examined primary legal and institutional materials. These included the United Nations Convention on the Law of the Sea (UNCLOS), official United Nations documents, materials produced by the International Law Commission, and relevant international judicial or arbitral materials where they directly addressed baselines, maritime delimitation, geographical features, or changing coastal conditions. Official institutional versions were preferred over secondary reproductions of legal documents.

Sources were included when they addressed at least one of the following areas: (1) legal principles governing maritime baselines or boundary delimitation; (2) geospatial methods used in maritime boundary analysis; (3) satellite-based coastline or shoreline extraction; (4) positional accuracy and uncertainty of satellite-derived shorelines; (5) the effects of erosion, accretion, or sea-level rise on coastlines and maritime reference features; or (6) the legal use and interpretation of maps, coordinates, satellite imagery, and other forms of geospatial information. Studies concerned solely with image-processing performance without a meaningful connection to coastal positioning or maritime applications were excluded. Sources lacking sufficient

bibliographic information or a traceable publisher, DOI, or official institutional source were also excluded.

2.3 Data Extraction and Analysis

The selected literature was reviewed using a thematic analytical approach. Information was extracted on the legal issue addressed, type of geospatial data used, remote sensing platform or spatial method where applicable, definition of the coastline or shoreline, reported sources of positional uncertainty, treatment of maritime baselines, and the main legal or governance implications identified by each source.

The literature was then organized into five analytical themes. The first concerned the legal foundations of maritime baselines and delimitation under the law of the sea. The second examined the contribution of geospatial data and geographic information systems to the representation and analysis of maritime boundaries. The third focused on satellite remote sensing for coastline identification and change detection, including the use of Landsat and Sentinel imagery. The fourth addressed technical uncertainty and the distinction between a shoreline detected from imagery and a baseline recognized for legal purposes. The fifth examined dynamic coastlines, particularly erosion, accretion, and sea-level rise, and their implications for the stability of maritime reference features and maritime governance.

Rather than comparing studies only according to their technical performance, the synthesis examined how findings from remote sensing and geospatial research relate to legal requirements. Particular attention was given to situations in which the physical coastline observed from satellite imagery may differ conceptually or spatially from the legally relevant low-water line or an officially recognized baseline. This comparative interpretation made it possible to identify areas where geospatial technologies can provide useful scientific evidence, as well as circumstances in which technical observations require additional legal, hydrographic, or geodetic interpretation before being used in maritime boundary processes.

The final synthesis was narrative and thematic. Findings from legal scholarship were compared with evidence from geospatial and remote sensing studies to identify areas of convergence, methodological limitations, and unresolved questions. This approach was intended to preserve the distinction between scientific observation and

legal determination while providing an interdisciplinary understanding of how both contribute to accurate and defensible maritime boundary governance.

3. Result and Discussion

3.1 Maritime Baselines as Legal and Geospatial Reference Features

The reviewed literature shows that maritime boundary analysis begins with a basic but important distinction between a coastline observed as a physical feature and a baseline recognized for legal purposes. Under Article 5 of UNCLOS, the normal baseline is the low-water line along the coast as marked on large-scale charts officially recognized by the coastal State (United Nations, 1982). The wording itself connects law with spatial information. The low-water line is a geographical feature, but its function as a baseline is established through a legal framework and official State recognition.

This distinction becomes more important when maritime delimitation involves two States. Baselines provide the geographical reference from which maritime entitlements are generated, but delimitation is not simply a technical exercise of extending lines seaward. Article 15 of UNCLOS addresses territorial-sea delimitation through the median-line principle, subject to historic title or other special circumstances. For the exclusive economic zone and continental shelf, Articles 74 and 83 require delimitation by agreement on the basis of international law in order to achieve an equitable solution (United Nations, 1982). Thus, geospatial analysis can determine distances, construct equidistance lines, identify relevant coastal points, and visualize competing claims, but the final boundary remains governed by legal rules and the circumstances of the case.

The same relationship can be seen in the treatment of archipelagic States. UNCLOS permits qualifying States to draw archipelagic baselines joining appropriate points of the outermost islands and drying reefs, subject to specific geographical requirements. These lines must also be represented on charts or through geographical coordinates that allow their position to be determined (United Nations, 1982). This makes the accuracy of coordinates, coastal representation, geodetic reference systems, and spatial data management relevant to legal implementation, although none of these technical elements independently creates a lawful maritime entitlement.

From a geospatial perspective, therefore, maritime boundaries can be understood as legal lines constructed through geographically referenced information. Their

reliability depends not only on the legal rule being applied but also on whether the underlying spatial information represents the intended coastal feature correctly. This is where remote sensing and geographic information systems have become increasingly useful.

3.2 Remote Sensing as a Source of Coastal Spatial Information

Satellite remote sensing has considerably changed the way coastal environments can be observed. Repeated Landsat and Sentinel acquisitions make it possible to examine coastline position over long periods without requiring continuous field surveys. Studies using these datasets have demonstrated that automated and semi-automated techniques can identify land-water boundaries, reconstruct shoreline histories, and detect erosion and accretion at local to global scales (Luijendijk et al., 2018; Sánchez-García et al., 2020; Vos et al., 2023). Luijendijk et al. (2018), for example, used decades of satellite observations to analyze sandy shoreline change worldwide, illustrating the value of Earth observation for identifying spatial trends that would be difficult to document through field observations alone.

More recent techniques have moved beyond simple pixel classification. Sánchez-García et al. (2020) developed an approach for extracting instantaneous shorelines from Landsat 8 and Sentinel-2 imagery, while Pardo-Pascual et al. (2024) evaluated automatically extracted Sentinel-2 shorelines using the Shoreline Analysis and Extraction Tool. These developments demonstrate that medium-resolution satellite imagery can provide more detailed shoreline positions than its nominal pixel size might initially suggest when appropriate sub-pixel methods and processing procedures are applied.

For maritime boundary studies, this capability is useful in several ways. Remote sensing can assist in identifying coastal configurations, observing changes around islands and headlands, documenting erosion and accretion, and providing a consistent spatial record for areas where conventional surveys are limited. In a geographic information system, these observations can then be combined with coordinate data, official charts, administrative boundaries, geodetic information, and proposed maritime limits. The value of GIS lies less in producing a legally valid boundary automatically than in allowing the spatial consequences of different legal and geographical assumptions to be examined transparently.

Research in Indonesia also demonstrates the practical relevance of combining coastline information with boundary analysis. Prayogo and Sukoco (2021) showed that changes in Indonesian regulations governing regional sea-boundary determination were accompanied by differences in technical procedures for constructing maritime limits. Their study illustrates that even within domestic maritime governance, legal rules and cartometric procedures are closely connected.

Remote sensing therefore provides an increasingly rich source of evidence about the physical coast. Nevertheless, the review also shows that greater spatial availability does not remove the need to examine how accurately a satellite-derived line represents the particular coastal feature required by law.

3.3 Accuracy and Uncertainty of Satellite-Derived Shorelines

A recurring issue in the remote sensing literature is that there is no single shoreline that can be observed independently of environmental conditions and methodological choices. In optical imagery, a shoreline is commonly derived from the spectral difference between water and non-water surfaces. The resulting line may represent an instantaneous land-water interface rather than a fixed tidal datum such as the low-water line referred to in Article 5 of UNCLOS. Pucino et al. (2022) explicitly describe the remote-sensing shoreline in relation to the boundary separating water and non-water classes in satellite imagery.

This difference is critical for legal interpretation. The position visible in a satellite image can shift according to tidal level, wave run-up, beach slope, sediment characteristics, image resolution, atmospheric conditions, and the classification algorithm. A satellite observation acquired during higher water conditions, for example, may place the apparent waterline landward of the low-water line that is legally relevant to a normal baseline. Conversely, variations in beach morphology may cause a relatively small vertical change in water level to translate into a considerable horizontal difference in shoreline position.

Validation studies confirm that these uncertainties cannot be treated as uniform. Pucino et al. (2022) compared Sentinel-2-derived instantaneous shorelines with 47 survey-grade UAV datasets collected across 15 coastal sites. Their results showed substantial spatial variability in shoreline extraction performance and indicated that the

method performing best at one section of coast may not necessarily be optimal elsewhere.

Vos et al. (2023) reached a related conclusion when benchmarking widely used satellite-derived shoreline algorithms using Landsat and Sentinel-2 imagery. The comparison demonstrated that shoreline accuracy depends on both the algorithm and the coastal environment, reinforcing the need for validation and standardized evaluation rather than assuming that a particular extraction technique has universal accuracy.

Pardo-Pascual et al. (2024) similarly evaluated Sentinel-2-derived shorelines across different coastal settings and demonstrated that automated extraction can provide useful spatial information, but its reliability must be assessed in relation to the characteristics of the coast and the input data.

These findings have a direct implication for maritime boundary work. Positional uncertainty should be treated as part of the evidence rather than hidden during cartographic processing. A satellite-derived coastline used in a legal or administrative boundary analysis should therefore be accompanied, where possible, by information on image acquisition time, spatial resolution, tidal conditions, extraction technique, georeferencing, positional accuracy, and validation data. Without this information, a visually precise vector line may suggest a degree of certainty that the underlying observation does not actually support.

The importance of explicitly considering uncertainty is consistent with hydrographic practice more broadly. International Hydrographic Organization standards place strong emphasis on positioning and measurement uncertainty in hydrographic surveys. The current S-44 standards provide technical requirements for survey quality and accuracy, although these standards should not be interpreted as rules for determining the legal validity of maritime baselines (International Hydrographic Organization, 2024). Their relevance here lies in the broader principle that spatial information used for maritime purposes needs a documented and appropriate level of positional reliability.

3.4 From Geospatial Evidence to Legal Recognition

The synthesis of legal and technical literature indicates that the most important conceptual boundary lies between geospatial evidence and legal authority. Satellite

imagery can show where a waterline appeared at a particular moment. A GIS can calculate distances from selected points with high computational precision. Neither, by itself, determines which geographical feature must be legally used or whether a particular line has received the recognition required under national or international law.

This is especially clear in Article 5 of UNCLOS. The Convention does not define the normal baseline simply as any coastline detectable using the most accurate available technology. It refers to the low-water line as represented on large-scale charts officially recognized by the coastal State (United Nations, 1982). Consequently, a newly extracted satellite coastline may be scientifically newer or spatially more detailed than an existing chart while still lacking the legal status of the officially recognized baseline.

This does not reduce the evidentiary value of satellite observations. Rather, it clarifies their proper function. Remote sensing may help identify discrepancies between current physical conditions and older cartographic information, provide independent evidence of coastal change, support hydrographic survey planning, assist in selecting or reviewing potential base points, and document environmental processes affecting coastal features. In disputed or technically complex areas, multiple geospatial sources may also be compared to assess whether apparent differences arise from actual coastal change, different tidal datums, cartographic generalization, positional uncertainty, or the use of different coordinate reference systems.

The review therefore suggests a layered approach to evidence. At the first level is the physical observation, such as the land-water interface detected from imagery. The second level concerns geospatial interpretation, including tidal correction, datum transformation, shoreline extraction, coordinate verification, and uncertainty analysis. The third level is legal characterization, where the relevant feature is assessed against UNCLOS, national law, official charts, deposited coordinates, agreements, or applicable judicial decisions. Only after these stages have been distinguished can the evidence be used appropriately in maritime boundary analysis.

This layered interpretation is particularly important because technical precision and legal relevance are not the same concept. A line with sub-pixel spatial precision may still represent the wrong legal shoreline indicator. Conversely, an officially established coordinate may continue to carry legal significance even when the physical coast surrounding it has subsequently changed. The central issue is therefore not whether

remote sensing is sufficiently sophisticated to "determine" maritime boundaries, but how its observations can be incorporated into a legally controlled process.

Table 1. Relationship between Geospatial Information and Maritime Boundary Law

Component	Geospatial contribution	Main limitation	Legal significance
Satellite imagery	Observes coastal configuration and land-water interface	Depends on acquisition time, tide, resolution, waves, and sensor characteristics	Supporting evidence of physical coastal conditions
Satellite-derived shoreline	Provides repeatable shoreline positions and change records	May represent an instantaneous waterline rather than the legally relevant low-water line	Requires legal and hydrographic interpretation
GIS	Integrates coordinates, coastlines, base points, zones, and charts	Results depend on input data, projection, datum, and assumptions	Supports cartometric analysis and visualization
Geodetic coordinates	Provide reproducible spatial positions	Datum or transformation errors may shift locations	Essential for defining and communicating maritime limits
Nautical or official charts	Provide authoritative cartographic representation	May not always reflect the most recent physical coastal change	Legal importance where UNCLOS requires officially recognized charts
Hydrographic survey data	Provide high-quality positional and tidal information	More costly and spatially limited than satellite monitoring	Strengthens technical reliability of maritime reference information

The table illustrates why an interdisciplinary approach is required. No single dataset fulfils every legal and technical function. Satellite imagery offers temporal

coverage; hydrographic and geodetic observations provide controlled measurement; GIS provides analytical integration; and law determines which spatial elements are relevant and what legal consequences follow from them.

3.5 Dynamic Coastlines and the Question of Maritime Stability

The interaction between physical and legal geography becomes particularly visible where coastlines change over time. Satellite records demonstrate that erosion and accretion can produce measurable shoreline movement over periods ranging from individual events to several decades (Luijendijk et al., 2018; Vos et al., 2023). Such changes raise a legal question: if a maritime entitlement has been constructed from coastal reference features, should changes in those features automatically produce changes in the legal limits of the maritime zone?

The traditional discussion has often been framed through the concept of ambulatory baselines, under which a baseline may move as the physical coastline changes. However, recent State practice and legal scholarship indicate increasing concern with stability and legal certainty. Anggadi (2022) found that States have increasingly invoked legal stability when addressing the potential effect of climate-induced sea-level rise on maritime zones. This practice challenges a simple assumption that every physical movement of the coast must automatically result in a corresponding movement of maritime limits.

Wendebourg (2023) likewise examined the ambulatory thesis against developing State practice and highlighted the changing legal discussion surrounding geographical change and maritime zones. The issue is particularly significant for low-lying and archipelagic States, where shoreline retreat or the alteration of small coastal features could otherwise have consequences extending far beyond the immediate coastal area.

The International Law Commission's work on sea-level rise has moved this debate further. In its 2025 final report, the Study Group examined the legal effects of sea-level rise on baselines, outer limits, maritime delimitations, and the exercise of coastal-State rights. The report reflects a strong concern with preserving legal stability and avoiding the reopening of duly established maritime boundaries simply because physical coastlines subsequently change as a consequence of climate-related sea-level rise (International Law Commission, 2025).

Oral (2025) similarly notes that the relationship between sea-level rise and maritime boundaries has developed from an area of substantial uncertainty toward greater clarity as State practice and international legal work have evolved.

These legal developments affect how remote sensing evidence should be interpreted. Increasingly accurate observation of shoreline retreat does not necessarily mean that a previously established legal maritime limit moves at the same rate or at all. Remote sensing may provide compelling evidence that the physical coast has changed, but the legal consequence of that change remains a separate question. In this respect, improvements in Earth observation make the distinction between physical and legal geography more visible rather than eliminating it.

3.6 Implications for Indonesia and Archipelagic Maritime Governance

The relationship between law and geospatial evidence is especially relevant to Indonesia because its maritime geography is characterized by thousands of islands, long coastlines, narrow inter-island waters, and numerous coastal features that may be important for maritime administration. As an archipelagic State, Indonesia operates within a legal regime in which the location and representation of islands, reefs, coastal reference features, baselines, and geographical coordinates have direct implications for the organization of maritime space.

Remote sensing offers clear advantages in this setting. Repeated satellite imagery can support monitoring of remote islands and rapidly changing coastlines, identify areas requiring new field or hydrographic observations, and provide consistent spatial records across areas that would be costly to survey continuously. GIS can then integrate these observations with legal and administrative information to support boundary evaluation and maritime governance.

However, the Indonesian context also demonstrates why legal and technical procedures cannot be separated. Prayogo and Sukoco (2021) found that changes in regulations governing regional sea-boundary determination affected the technical procedures used for cartometric boundary construction. This indicates that a geospatial method does not operate independently from the regulatory framework under which it is applied.

The practical implication is that Indonesia would benefit most from remote sensing when it is used within a hierarchy of spatial evidence. Satellite imagery can

serve as a monitoring and analytical source; geodetic and hydrographic information can provide higher-order positional control where required; official charts and coordinates provide formal spatial references; and the applicable legal framework determines their use and effect. This approach avoids two opposite problems: relying on outdated coastal information merely because it is formally established, or assuming that the newest satellite-derived coastline automatically has legal authority.

3.7 Toward an Integrated Legal-Geospatial Approach

Taken together, the reviewed literature does not support the idea that remote sensing can replace conventional legal and hydrographic processes in maritime boundary delimitation. It does, however, demonstrate that satellite observation has become too useful to remain peripheral to maritime boundary analysis. Its main contribution is the ability to provide repeatable, spatially extensive, and temporally detailed observations of coastal conditions.

A more appropriate approach is therefore to integrate remote sensing into a legal-geospatial workflow. Satellite imagery should first be treated as an observation of physical coastal conditions. The resulting shoreline should then be evaluated for positional accuracy, acquisition conditions, tidal effects, spatial reference, and methodological uncertainty. Where the information is intended to support a maritime baseline or boundary analysis, it should be compared with official charts, geodetic coordinates, hydrographic information, and the coastal feature required under the applicable legal rule. Only after these technical questions have been addressed should the spatial evidence be interpreted in legal terms.

Such integration also improves transparency. If the origin, uncertainty, datum, date, and legal status of each spatial layer are documented, decision-makers can distinguish between an observed physical coastline, an analytical shoreline, an officially recognized baseline, and a negotiated or adjudicated maritime boundary. Treating these different lines as interchangeable creates legal and technical ambiguity; maintaining the distinction makes geospatial evidence more useful.

The central finding of this review is therefore not that satellite technology is changing the law of maritime delimitation, but that it is changing the quality, frequency, and visibility of the geographical evidence available to apply that law. The legal framework continues to determine maritime entitlements and boundaries, while

remote sensing, geodesy, hydrography, and GIS provide increasingly sophisticated evidence about the geographical setting in which those legal rules operate. Their integration offers a stronger basis for maritime boundary governance, particularly where coastal environments are dynamic and where both spatial accuracy and legal certainty are required.

4. Conclusion

This review shows that maritime boundary delimitation depends on a close relationship between legal rules and reliable geospatial information. Remote sensing, GIS, geodesy, and hydrographic data can provide valuable evidence for identifying coastal features, monitoring shoreline change, analyzing coordinates, and supporting the construction and evaluation of maritime limits. However, the coastline detected from satellite imagery should not automatically be regarded as a legally recognized baseline. Its relevance depends on the legal framework, the type of coastal feature represented, positional accuracy, tidal conditions, image characteristics, and whether the information has been formally recognized for legal purposes.

The findings also highlight the importance of distinguishing between physical coastal change and legal change. Erosion, accretion, and sea-level rise may alter the observed position of the coastline, but these changes do not necessarily produce an equivalent shift in legally established baselines or maritime boundaries. This distinction has become increasingly important as international legal discussions place greater emphasis on stability and legal certainty in maritime zones. For archipelagic States such as Indonesia, the most effective approach is therefore not to rely on a single source of spatial information, but to combine satellite observations with geodetic, hydrographic, cartographic, and legal data. Such integration can improve the accuracy and transparency of maritime boundary analysis while ensuring that technological developments remain consistent with the requirements of the law of the sea. Future research should further examine practical standards for assessing the legal reliability of satellite-derived coastal information and its use in maritime boundary governance.

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