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Tenure arrangement, cadastral survey system, and land valuation
addressing tenure insecurity in the aquatic land settlements of Riau Islands Province, Indonesia

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SUMMARY

Riau Islands Province in Indonesia presents a unique challenge for land administration due to its predominantly aquatic landscapes and culturally-related coastline settlements development. Complex governance factors, along with the rapid growth of these settlements, have exacerbated tenure insecurity. Rights and their spatial realization over land parcels are unclear, potentially leading to competing claims and disputes. The lack of proper valuation frameworks for coastal parcels hampers effective taxation and investment. Academics have underscored the importance of crafting context-specific solutions to strengthen tenure security in coastline areas by considering the important role of people, governance, and technology. Reducing tenure insecurity is crucial for achieving sustainability and has been highlighted as one of the goals of the Indonesian National Agrarian Reform to reduce land disparities, and also the international agenda of the Sustainable Development Goals (particularly SDG 1, 10, and 15), the fit-for-purpose land administration initiatives, and the Voluntary Guidelines of Responsible Governance of Tenure of Land, Fisheries, and Forests in the Context of National Food Security by Food and Agricultural Organization (FAO). The goal of this thesis is to develop and assess tailored solutions for strengthening tenure security, aiming to obtain legal, spatial, and value-based certainty through tenure arrangement, cadastral survey, and valuation of the aquatic land in the coastline areas of Riau Islands Province. To achieve this goal, three main contributions are:

Establishing proper tenure arrangements by defining the optimum tenure forms and their compliance with spatial plans and physical settings. Tenure arrangement is defined as the process to organize and configure any of the existing relationships between people and land (i.e., tenure forms) adhering to relevant considerations and restraints. Establishing an adapted tenure arrangement in the coastal settlements means involving balanced consideration of legal frameworks, community needs, spatial plans, and the unique physical characteristics of the coastal environment. To contextualize the necessity of administering land in the coastal areas, we described historical and administrative arguments and connected the concept of tenure security to national policy and international agendas that aim to reduce land disparities. Serving as the framework for analysis, foundational concepts such as the continuum of land tenure (one of the legal frameworks of the fit-for-purpose approach), the tripartite view of security, and the positioning of aquatic lands within the marine and land regimes were elaborated. Assessment to find the preferred secure situation to accommodate the communities' view was done using Analytic Hierarchy Process (AHP) analysis. The communities most preferred "unlimited duration of occupation, administrative recognition, and no eviction" as three top secure situations. In contrast, their least three preferred were "convenience in transaction, short duration, and convenience for commercial uses". This indicates a preference of the communities to view their aquatic land, regardless of its dynamic, as a place for stable living rather than as an asset that can be easily transactioned. We then deployed the Fuzzy Technique for Order Performance by Similarity to Ideal Solution (Fuzzy TOPSIS) analysis to gain the most suitable forms as the trade-off between the preferred secure situations and the applicable tenure forms with their inherent provisions, as defined by regulations and practices. This study's findings reveal that in total there are 11 suitable tenure forms, and the five most optimal tenure forms are, in order: the temporal or fixed-term formal rights of Right of Use (*Hak Pakai/HP*) and Right to Build (*Hak Guna Bangunan/HGB*); followed by the non-statutory Possession Letter (*Surat Keterangan Tanah*); then the formal Communal Right (*Hak Komunal/HK*); and finally the non-statutory Numpang Bangun (NB system). The tenure forms were then compared with spatial plans as the manifestation of spatial guidance of development, as well as with physical characteristics, to provide a more spatially sensitive tenure allocation. This study found that housing and mixed-use zones are where most tenure forms are spatially applicable. IL/IP (Location/Utilization Permit)—specifically via KKPR (Conformity of Spatial Utilization Activities) document—and HP were identified as the two most prevalent forms to be applied within spatial planning zones. "Connected to the mainland, temporarily submerged, and

with the presence of stilt structures and buildings" is the most appropriate coastal setting for tenuring aquatic lands. Rights, restrictions, and responsibilities information associated with aquatic land parcels were also discovered to pursue the certainty of actionable guidance for land use management in coastal settlements. In this section, it is concluded that the findings of this study point to the recognition of hybrid tenure systems to strengthen security of tenure in the coastline settlements while reflecting the diverse ways land are managed in practice.

Assessment of the UAV system for cadastral boundary acquisition was conducted concerning the reality that secure tenure requires not only robust legal frameworks but also precise spatial representations of land parcel boundaries through proper cadastral services. This study employed Unmanned Aerial Vehicles (UAVs) as the survey system of fit-for-purpose approaches that align with global trends in land administration systems to generate orthophoto maps. Specific for building footprints as the built-up aquatic parcel boundaries, we used two semi-automatic feature extraction methods: Object-Based Image Analysis (OBIA) and Mapflow.AI, a pre-trained artificial intelligence technique utilizing Mask R-CNN (Mask Region-based Convolutional Neural Network). These object detection and segmentation methods analyzed spatial, spectral, and texture characteristics to extract the boundaries. Correctness, completeness, and quality assessments validated the results, revealing the strengths and weaknesses of each technique. The OBIA method performed better by consistently receiving higher scores for completeness, correctness, and quality, indicating greater reliability and accuracy. However, we also found that both methods struggled in areas with dense, irregularly shaped buildings, and performed better in more distinct and water-locked building clusters where buildings are clearly separated by roads or bodies of water. By evaluating these methods' applicability to different areas and building types, the study offers guidance on implementing effective, image-based techniques for spatially securing tenure in coastal settlements. Accurate and verifiable cadastral boundaries are critical to address tenure insecurity from a spatial perspective.

Developing and assessing aquatic land valuation in the coastline settlements is the third contribution of the research. Besides legal and spatial certainty, another crucial aspect in establishing tenure security on a parcel is the certainty of its value. Stipulated and accurate land value information contributes to stable land taxation and investment. We listed the potential affecting factors from economic, legal, and physical environmental attributes from literature analysis and field observation to link the theory with the context of the study area's distinctive characteristics and to produce context-sensitive factors. The results showed that physical environmental factors outnumber the other factors, underscoring their crucial role in developing a sensitive model in coastline settlements. We generated those value-affecting factors through GIS-based analysis, using the produced UAV orthophoto as the primary data source. The study then developed a GIS parcel-based hedonic mass valuation that uses a comparison-score technique. The detailed land value maps, which provide a spatial representation of value variations across the study area that precisely follow the boundary of the parcel, reveal the certainty assignation of the value specific to each parcel. Multiple regression analysis was conducted to run a statistical tests to understand the model's rationality. The result indicates that, although there may be some unexplained variability remaining, the model demonstrates strong explanatory power, capturing a substantial portion of the variance. The general investigation highlights the potential of integrating UAV-based surveys and GIS technologies in optimizing land valuation precision.

This thesis denotes an overall conclusion that the provision of fit-for-purpose land information (legal, spatial, and value attributes) through multi-tenure arrangements and its proposed protocol, low-cost and fast-oriented cadastral survey systems, and context-specific land valuation techniques are promising comprehensive approaches. These strategies demonstrate the potential multidimensional security services that complement each other in addressing tenure insecurity in the aquatic settlements of the Riau Islands Province.

ZUSAMMENFASSUNG

Die Provinz Riau in Indonesien stellt aufgrund ihrer überwiegend aquatischen Landschaften und der kulturell bedingten Entwicklung der Küstensiedlungen eine besondere Herausforderung für die Landverwaltung dar. Komplexe Governance-Faktoren haben zusammen mit dem raschen Wachstum dieser Siedlungen die Unsicherheit der Besitzverhältnisse verschärft. Die Rechte und ihre räumliche Verwirklichung an Landparzellen sind unklar, was zu konkurrierenden Ansprüchen und Streitigkeiten führen kann. Das Fehlen eines angemessenen Bewertungsrahmens für Küstenparzellen behindert eine effektive Besteuerung und Investitionen. Wissenschaftler haben unterstrichen, wie wichtig es ist, kontextspezifische Lösungen zu entwickeln, um die Sicherheit der Besitzverhältnisse in Küstengebieten zu verbessern, indem die wichtige Rolle von Menschen, Verwaltung und Technologie berücksichtigt wird. Die Verringerung unsicherer Besitzverhältnisse ist von entscheidender Bedeutung für das Erreichen von Nachhaltigkeit und wurde als eines der Ziele der indonesischen Agrarreform zur Verringerung von Landdisparitäten hervorgehoben, ebenso wie die internationale Agenda der Ziele für nachhaltige Entwicklung (insbesondere SDG 1, 10 und 15), die Initiativen für eine zweckmäßige Landverwaltung und die freiwilligen Leitlinien für eine verantwortungsvolle Verwaltung von Land-, Fischerei- und Waldbesitz im Zusammenhang mit der nationalen Ernährungssicherheit der Ernährungs- und Landwirtschaftsorganisation (FAO). Das Ziel dieser Arbeit ist es, maßgeschneiderte Lösungen zur Stärkung der Besitzsicherheit zu entwickeln und zu bewerten, um durch Besitzregelungen, Katastervermessungen und Bewertungen der Wasserflächen in den Küstengebieten der Provinz Riau-Inseln rechtliche, räumliche und wertbezogene Sicherheit zu erreichen. Um dieses Ziel zu erreichen, sind drei Hauptbeiträge vorgesehen:

Festlegung geeigneter Tenure-Arrangements durch Definition optimaler Tenure-Formen und deren Übereinstimmung mit räumlichen Plänen und physischen Gegebenheiten.

Die Regelung von Besitzverhältnissen ist definiert als der Prozess der Organisation und Gestaltung bestehender Beziehungen zwischen Menschen und Land (d. h. Besitzformen) unter Berücksichtigung relevanter Überlegungen und Einschränkungen. Eine angepasste Regelung der Besitzverhältnisse in den Küstensiedlungen bedeutet eine ausgewogene Berücksichtigung des rechtlichen Rahmens, der Bedürfnisse der Gemeinschaft, der Raumordnungspläne und der einzigartigen physischen Merkmale der Küstenumgebung. Um die Notwendigkeit der Landverwaltung in den Küstengebieten zu kontextualisieren, haben wir historische und verwaltungstechnische Argumente beschrieben und das Konzept der Besitzsicherheit mit der nationalen Politik und internationalen Agenden verknüpft, die darauf abzielen, Landdisparitäten zu verringern. Als Analyserahmen dienten grundlegende Konzepte wie das Kontinuum des Landbesitzes (einer der rechtlichen Rahmen des Fit-for-Purpose-Ansatzes), die dreigliedrige Sichtweise der Sicherheit und die Positionierung von Wasserland innerhalb der Meeres- und Landregime. Die Bewertung, um die bevorzugte sichere Situation zu finden, die den Ansichten der Gemeinschaften entspricht, wurde mit Hilfe der Analyse des analytischen Hierarchieprozesses (AHP) durchgeführt. Die Gemeinden bevorzugten "unbegrenzte Dauer der Nutzung, administrative Anerkennung und keine Räumung" als die drei sichersten Situationen. Umgekehrt waren die drei am wenigsten bevorzugten Situationen "Bequemlichkeit bei Transaktionen, kurze Dauer und Bequemlichkeit für kommerzielle Zwecke". Dies deutet darauf hin, dass die Gemeinschaften ihr Wasserland, unabhängig von seiner Dynamik, eher als einen Ort für ein stabiles Leben denn als einen Vermögenswert betrachten, der sich leicht veräußern lässt. Anschließend haben wir die Fuzzy-Analyse TOPSIS (Fuzzy Technique for Order Performance by Similarity to Ideal Solution) angewandt, um die am besten geeigneten Formen als Kompromiss zwischen den bevorzugten sicheren Situationen und den potenziell anwendbaren Besitzverhältnissen aus den geltenden Vorschriften und Praktiken zu ermitteln. Die Ergebnisse dieser Studie zeigen, dass es insgesamt 11 geeignete Besitzformen gibt, und die fünf optimalsten Besitzformen sind, in dieser Reihenfolge: die

befristeten formalen Rechte des Nutzungsrechts (*Hak Pakai/HP*) und des Baurechts (*Hak Guna Bangunan/HGB*); gefolgt von dem nicht-gesetzlichen Besitzbrief (*Surat Keterangan Tanah*); dann das formale Gemeinschaftsrecht (*Hak Komunal*/HK) und schließlich das nicht-gesetzliche Numpang Bangun (NB-System). Die Besitzformen wurden dann mit Raumplänen als Ausdruck der räumlichen Steuerung der Entwicklung sowie mit physischen Merkmalen verglichen, um eine räumlich sensiblere Besitzzuweisung zu ermöglichen. Die Studie ergab, dass in Wohn- und Mischgebieten die meisten Besitzverhältnisse räumlich anwendbar sind. IL/IP (Standort-/Nutzungsgenehmigung) - insbesondere über das Dokument KKPR (Konformität von Raumnutzungsaktivitäten) - und HP wurden als die beiden häufigsten Formen identifiziert, die innerhalb von Raumplanungszonen angewendet werden. "Mit dem Festland verbunden, vorübergehend überflutet und mit Stelzenbauten und Gebäuden versehen" ist die am besten geeignete Küstenumgebung für die Pacht von Wasserflächen. Es wurden auch Informationen über Rechte, Beschränkungen und Verantwortlichkeiten im Zusammenhang mit Wasserparzellen ermittelt, um die Sicherheit einer handlungsfähigen Anleitung für das Landnutzungsmanagement in Küstensiedlungen zu gewährleisten. In diesem Abschnitt wird die Schlussfolgerung gezogen, dass die Ergebnisse dieser Studie auf die Anerkennung hybrider Besitzverhältnisse hinweisen, um die Sicherheit der Besitzverhältnisse in den Küstensiedlungen zu stärken und gleichzeitig die verschiedenen Arten der Verwaltung von Landrechten in der Praxis widerzuspiegeln.

Die Bewertung des UAV-Systems für die Erfassung von Katastergrenzen wurde unter Berücksichtigung der Tatsache durchgeführt, dass ein sicheres Eigentum nicht nur einen soliden rechtlichen Rahmen, sondern auch eine präzise räumliche Darstellung der Landgrenzen durch geeignete Katasterdienste erfordert. In dieser Studie wurde ein unbemanntes Luftfahrzeug (UAV) als zweckmäßiges Vermessungssystem eingesetzt, das mit den globalen Trends bei Landverwaltungssystemen übereinstimmt, um Orthophotokarten zu erstellen. Speziell für Gebäudegrundrisse als bebaute, aquatische Parzellengrenzen wurden zwei halbautomatische Methoden zur Merkmalsextraktion eingesetzt: Object-Based Image Analysis (OBIA) und Mapflow.AI, eine vortrainierte Technik der künstlichen Intelligenz, die Mask R-CNN (Mask Region-based Convolutional Neural Network) verwendet. Diese Methoden zur Objekterkennung und -segmentierung analysierten räumliche, spektrale und texturelle Merkmale, um die Grenzen zu extrahieren. Korrektheits-, Vollständigkeits- und Qualitätsbewertungen validierten die Ergebnisse und zeigten die Stärken und Schwächen der einzelnen Verfahren auf. Die OBIA-Methode schnitt besser ab, da sie durchweg höhere Werte für Vollständigkeit, Korrektheit und Qualität erhielt, was auf eine höhere Zuverlässigkeit und Genauigkeit hindeutet. Wir stellten jedoch auch fest, dass beide Methoden in Gebieten mit dichter, unregelmäßig geformter Bebauung Schwierigkeiten hatten und in klareren und von Wasser umgebenen Gebäudeclustern, in denen die Gebäude deutlich durch Straßen oder Gewässer getrennt sind, besser abschnitten. Durch die Bewertung der Anwendbarkeit dieser Methoden auf verschiedene Gebiete und Gebäudetypen bietet die Studie Anhaltspunkte für die Umsetzung effektiver, bildgestützter Techniken zur räumlichen Sicherung von Besitzverhältnissen in Küstensiedlungen. Genaue und überprüfbare Katastergrenzen sind von entscheidender Bedeutung, wenn es darum geht, unsichere Besitzverhältnisse aus einer räumlichen Perspektive zu betrachten.

Der dritte Beitrag der Forschung ist **die Entwicklung und Bewertung von Grundstückswerten in den Siedlungsgebieten des Wasserlandes.** Neben der rechtlichen und räumlichen Sicherheit ist ein weiterer entscheidender Aspekt bei der Schaffung von Besitzsicherheit für eine Parzelle die Gewissheit über ihren Wert. Festgelegte und genaue Informationen über den Bodenwert tragen zu einer stabilen Bodenbesteuerung und zu Investitionen bei. Wir haben die potenziellen Einflussfaktoren aus wirtschaftlichen, rechtlichen und physischen Umweltmerkmalen aus der Literaturanalyse und der Feldbeobachtung aufgelistet, um die Theorie mit dem Kontext der besonderen Merkmale des Untersuchungsgebiets zu verknüpfen und kontextabhängige Faktoren zu ermitteln. Die Ergebnisse zeigten, dass die physischen Umweltfaktoren den anderen Faktoren

überlegen sind, was ihre entscheidende Rolle bei der Entwicklung eines sensiblen Modells für Siedlungen an der Küste unterstreicht. Wir haben diese wertbeeinflussenden Faktoren durch eine GIS-basierte Analyse ermittelt, wobei wir das erstellte UAV-Orthofoto als primäre Datenquelle verwendeten. In der Studie wurde dann eine parzellenbasierte hedonische Massenbewertung auf GIS-Basis entwickelt, bei der ein Vergleichswertverfahren zum Einsatz kommt. Die detaillierten Bodenwertkarten, die eine räumliche Darstellung der Wertvariationen im gesamten Untersuchungsgebiet bieten, die genau der Parzellengrenze folgen, zeigen die sichere Zuweisung des Wertes für jede Parzelle. Mit Hilfe einer multiplen Regressionsanalyse wurden statistische Tests durchgeführt, um die Rationalität des Modells zu verstehen. Das Ergebnis zeigt, dass das Modell trotz der möglicherweise verbleibenden unerklärten Variabilität eine starke Erklärungskraft aufweist und einen wesentlichen Teil der Varianz erfasst. Die allgemeine Untersuchung hebt das Potenzial der Integration von UAV-basierten Vermessungen und GIS-Technologien zur Optimierung der Genauigkeit der Grundstücksbewertung hervor.

Diese Dissertation zieht die Gesamtschlussfolgerung, dass die Bereitstellung von zweckmäßigen Landinformationen (rechtliche, räumliche und wertbezogene Attribute) durch Mehrfachbesitzregelungen und das vorgeschlagene Protokoll, kostengünstige und schnell orientierte Katastervermessungssysteme sowie kontextspezifische Bodenbewertungstechniken vielversprechende umfassende Ansätze sind. Diese Strategien zeigen das Potenzial multidimensionaler Sicherheitsdienste, die sich gegenseitig ergänzen, um die Unsicherheit der Landnutzung in den aquatischen Siedlungen der Provinz Riau-Inseln zu bewältigen.

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1 INTRODUCTION

1.1 BACKGROUND

Indonesia is geographically situated between longitude 95° E and 141° E and between latitude 6° N and 115° S along the equator line. Stretching extensively that large, with more than 17.000 islands, over than 7,9 million km^2 of the sea including exclusive economic zones, Indonesia is then being the world's largest archipelagic state (Cribb and Ford, 2009). Indonesia's territory covers an area of more than 1.904.569 km^2. with about 95.181 km of coastlines (WRI, 2000). Indonesian coastal zone is around 24,3 million ha (Dahuri et al., 2001) and within 100 km inland from the coast, over 150 million people rely on marine resources for their livelihoods. Indonesia also has eight archipelago provinces (Figure 1) and 15,61% of 69.363 villages are coastal villages (BPS, 2016).

Figure 1. Eight Indonesian archipelago provinces

1.1.1 Geographical setting

This archipelagic character creates an intertwined and complicated situation of territorial governance. In tenure administration sector, for example, the government is required to deal with not only land tenure but also marine tenure and coastal tenure as well. Land in Indonesia practically is also governed in two ways: by the government through formal statutory or constitutional systems, and by the informal way through a traditional/customary governance system. As stated by the Food and Agriculture Organization (FAO, 2003), these various forms of tenure may create an intricate pattern of rights and interests.

Specific for coastal areas, it applies two management regimes: land-based regime and sea-based regime. It is unavoidable since, in essence, the coastal area consists of coastal lands and coastal waters, and geographically, the land-sea interface. This dual management creates a big challenge to avoid overlap practices on one side and the void on the other side. This multifaceted situation resonances the statement from the International Federation of Surveyors (FIG, 2008) that describes coastal areas as one of the most complex areas to manage due to big demand and interests. Many interplaying sectors take place in the areas such as city administration, mining, fisheries, public works, housing, forestry, environment, transportation, tourism. Cicin-Sain and Knecht (1998) revealed, as cited in Tamtomo (2006), on coastal waters, there are 29 activities, and if they are set in an activity matrix, there will be 100 pairs of activities conflicting each other. Besides providing natural resources and environmental services, coastal areas function as a place to gain a livelihood and accommodation for particular human needs such as mobility, leisure, and settlement.

One of the Indonesian archipelagic provinces is Kepulauan Riau or Riau Islands, located on the northwest side of the country. Despite having only two municipalities (Batam and Tanjungpinang) and five regencies (Bintan, Lingga, Karimun, Natuna, and Anambas Islands), Kepulauan Riau is recognized as the most prominent archipelago province. Table 1 presents the statistics of the province as the archipelago province. The land covers only four percent of its 2.408 islands, and the sea occupies 96 percent of its total area of 252.601 square kilometers (Pemprov Kepulauan Riau, 2015). This province has 361 out of 425 coastal villages, which means 86,99% of its villages are coastal villages.

Table 1. Riau Islands Province statistics

No.	Province name	Capital city	Statistics	
1	Kepulauan Riau (Riau Islands)	Tanjungpinang	Total area	251.810,71 sq. km
			Land area	10.595,41 sq. km (4% of the total area)
			Water area	241.215,3 sq. km (96% of the total area)
			No. of islands	2.408
			Coastline length	2.368 km
			No. of coastal villages	361 out of 425 (87% of the total number of villages)

Sources: Badan Pusat Statistik (2016)

Having this archipelago setting, which is also common in other archipelago provinces, there exists a unique local settlement pattern in Kepulauan Riau territory. By tradition, the villages have been developed in shallow-shore water or the tidal area along the coastlines or shorelines. Ivey (2015) states that the area along the coastline (e.g., tidelands, shorelands, harbor areas, and the beds of navigable waters) are called aquatic land area. Meaning, the land that gain aquatic influences. Local people call this type of shore settlement as "pemukiman pelantar" and the land where they build the houses are called "tanah pelantar" or "tanah laut". "Tanah" means land in English. For convenience, this thesis also denotes shore settlements as aquatic land settlements or coastline settlements (Figure 2).

A coastal settlement in Penyengat Island
(Photo source: author's collection)

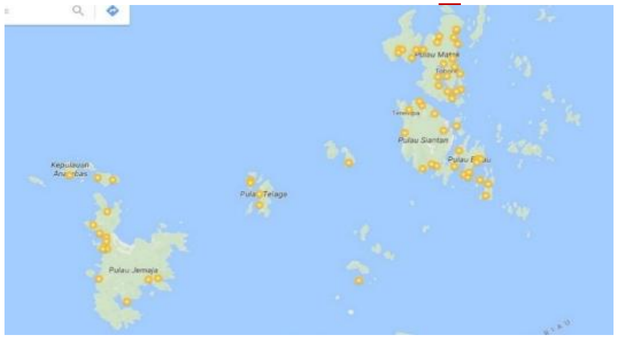
Aerial view of a coastal settlement area
(Source: tanjungpinangpos.id)

Figure 2. The settlements in Penyengat Island

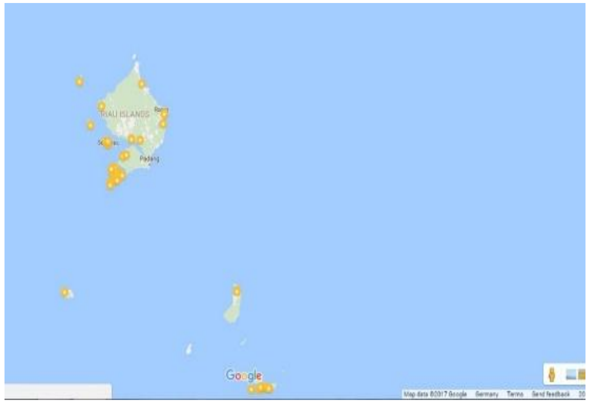
Most of the aquatic land settlements were built dozens or hundreds of years ago in the era of Malay Kingdoms (17th-19th century). The rest were built in the following decades and years and still go on until nowadays. The main reason why local communities in Riau Islands, which are mostly Malay and Bugis ethnic group descent, prefer to build their houses in shorelines rather than in inland areas is due to the condition that most of them are traditional and small fishermen. They then perceive that their life connects to and somehow are more dependent on the sea than to the land in many aspects, e.g., in livelihood, living habits, trade affairs, and transportation (Surianto, 2012). In the last few decades, for a trading reason, Chinese ethnic group joined the communities, especially the ones located near town centers, and create a more multi-cultural area in the settlements.

Although nowadays more areas are built and developed in the hinterland, some of the coasts in Kepulauan Riau big islands, e.g., Tarempa in Anambas Regency and Tanjung Balai Karimun in Karimun Regency, and in some small islands such as Penyengat, Dendun, Tambelan, and Senayang are still developing and even more populated than in the hinterland areas. Since there is no data available of how many settlements exist in the province, we ran a visual inspection to high-resolution satellite imagery from multiple sources (e.g., Google, Bing Maps). Our own investigation (Figure 3) reveals at least there are 309 spots of the settlements spreading over the province, located in either big islands such as Bintan, Batam, Singkep, Siantan, Natuna, or in small islands (i.e., area < 2.000 sq km) such as Dendun, Penyengat, Senayang, Mapur (Appendix 1). The settlements are present from Laut Island in the northenmost part of the province to Singkep Island in the southern part, with the area of a single settlement ranging from around 0,3 to 45 hectares. A rough calculation, dividing the area by the average building size, indicates at least 86.275 buildings are spread along the coastlines. Therefore, with an approximate 10 percent deviation, we can assume there are between 77.647 and 94.902 individual parcel tenures within the area of around 910 hectares that need proper management in Riau Island province.

<table>
<tr><th>City/Regency, No. of settlements, area</th><th>Distribution of the settlements (in free scale view)</th><th>Imagery view of the settlement (in free scale view)</th></tr>
<tr><td>Batam City
71 settlements
~ 182 hectares</td><td rowspan="4"></td><td rowspan="4">

Coastline settlement in Tambelan Besar, Bintan Regency (area ~19,5 ha)</td></tr>
<tr><td>Tanjungpinang City
19 settlements
~ 101 hectares</td></tr>
<tr><td>Karimun Regency
35 settlements
~ 100 hectares</td></tr>
<tr><td>Bintan Regency
37 settlements
~ 81 hectares</td></tr>
<tr><td>Anambas Islands Regency
63 settlements
~ 195 hectares</td><td></td><td>

Coastline settlement in Matak Island (area ~ 7,6 ha)</td></tr>
</table>

Natuna Regency 39 settlements ~ 150 hectares		 Coastline settlement in Sedanau (area ~ 34 ha)
Lingga Regency 42 settlements ~101 hectares		 Coastline settlement in Bakung Island (area ~ 1,2 ha)

Source: Statistics (author investigation), images (Google)

Figure 3. Distributions of aquatic land settlements

1.1.2 Problematic situations in current land administration for coastline areas

Although this local way of residing creates a unique and typical tenure system and exists since long time ago, as well as be admitted by the country administration as a local and unique settlement pattern, administering the parcels on the aquatic land area, in the context of Indonesian land administration system is “wicked” in terms of vague and complex. At least three causes can explain this.

First, the propensity of the current Indonesian land administration system. The system, after its establishment in 1960 with Act No. 5 of 1960 about Basic Regulations on Agrarian Principles (hereinafter referred to as Basic Agrarian Law of 1960 or BAL), is too terrestrial-oriented in implementation. Although in fact there is actually some potential regulatory point of view that can be a legal foundation and support the land administration along the shoreline, practically, the system mostly functions only in Indonesia’s hinterland areas and neglects “the other type” of land including aquatic lands. *Second*, although there are apparatus and authorities of sea-governance in Indonesia under Ministry of Fisheries and Marine Affairs (KKP), the scope of duties does not specifically facilitate the administration of tenure, especially for individual(s) or small-scale land possession, in the shoreland areas.

Third, the complexity in the operational level of Indonesian land management in coastal areas. In the Jakarta coastal area (Jakarta Bay), for example, there are 43 stakeholders involved in its management (Sofiyah, 2013). We find there are 23 authoritative bodies (governmental agency and administration) from all tiers of the administration hierarchy (national, province, regency, sub-district, and village) operate in coastal areas of Kepulauan Riau Province. The nature of a coastal area itself as meeting place of the land-based regime and marine-based regime with all their influences in regulations underpins this situation, for example, the condition that Indonesia has two spatial planning systems that work in coastal regions. Regional Spatial Planning or *Rencana Tata Ruang Wilayah* (in short RTRW) shows the planning regulation from land-based regime (Christian et al., 2018). Zoning Plan for Coastal Areas and Small Islands or *Rencana Zonasi Wilayah Pesisir dan Pulau-Pulau Kecil* (in short RZWP3K) is reflecting a marine-based regime.

As a consequence, land tenure security is hindered. (FAO, 2002), defines land tenure security as “the certainty that a person’s rights to land will be recognized by others and protected in cases of specific challenges” (p. 18). Bazoglu et al. (2011) explain in a more wider way that security of tenure refers to recognition degree of rights that protects against forced evictions, the possibility of transferring rights, mortgage options, and access to credit under certain conditions. By stating “access to credit”, Bazoglu et al. argue that the ability to get a loan from financial institutions also become a relevant security indicator. In other definition, International Fund for Agricultural Development (IFAD, 2015) states that secure land tenure means that the holder might be able and engaged to control and manage land for his own needs.

The insecurity can be embodied in many situations, but the most obvious one is in the difficulty of land rights recognition or land registration, due to an unclear tenure arrangement or tenure uncertainty. Damayanti (2005) calls this situation “tenure confusion”, while de Cadiz (2018) use the term “irregular ownership”. The problem derives from the uncertainty of which tenure forms – or mostly simplified as land rights – that can be applied in coastline areas, which in turn, potentially bring the confusion of the entitlement consequences the holder could have or the responsibility the holder should be aware of, and how they should be established according to spatial plans and physical settings that play a role as spatial and regulatory restrictions ((see Table 2).

Dealing with uncertainty of rights in aquatic lands also means dealing with the proper cadastral objects and their boundary definition and determination. It is not clear what exactly the boundary of the aquatic land parcels is in regard to any particular tenure forms, where the boundary is supposed to be delimited by the involved parties and then measured by following cadastral principles. One example from the study area, the village administration in Dendun Island, argues that the possession of the parcel is limited by the appearance of the building. The area outside the building is considered a free area (open space area). Meaning, without buildings, there is no possession. This difference will show, from the perspective of good land governance, a practice of 'recognition inconsistency'. A clear definition and reliable measurement are essential, as rights to land do not exist in a physical form, and they have to be manifested through a boundary representation (either cartographically in the map or physically through some markings) that shows the claim of rights. Without suitable tenure forms and a clear determination of tenure form boundaries, one only keeps low certainty and clarity of his possessed land. This hinders their ability to use it as an asset because landholders are unsure of the rights' extent of usage, privilege, and constraints, which could lead to accidental law violations.

In formal system, difficulties in registering land can obstruct the proprietor for obtaining further benefits such as access to a loan from the bank, or in a specific term the benefit is called *collateralization effects*, which means the effects derive from increased access to formal credit (Hollingsworth, 2014). Land titles can be used as collateral against loans thereby reducing bank lending costs. In his research, Feder (1987) explains that the holder of titled land had increased access to formal credit (ranging from 52-521%) and this credit was cheaper, with informal credit being three times more expensive. Owning land certificate or other proof of claims also help the landholders bargaining to get a higher price in land transactions. The price difference between titled land and the ones without title may reach 10 percent higher (Directorate of Land Valuation, 2014).

The low certainty might put the land exposed to disputes. According to the United States Agency for International Development (USAID, 2013) land disputes refer to "competing or conflicting claims to rights to land by two or more parties, individuals or groups. The disputes are generally related to boundaries, overlapping use rights, access to land, competition for resources, ownership and inheritance". The lack of clarity often leads to the emergence of disputes, as it attracts new parties to establish occupations for a variety of interests (FIG, 2008).

Statistics from the Indonesian Presidential Staff Office (KSP) show that across Indonesian territory, in 2018, 3,263 land disputes were identified with a variety of scales and types (KSP, 2018). In its 2017 publication, the Consortium of Agrarian Reform (KPA) investigated that twenty-two of the disputes were the land conflicts in coastal areas and small islands (KPA, 2017). Dahuri et al. (2001) state that one of the leading causes of conflicts is incoherence in land use planning and tenure allocation. As written in the Head of National Land Agency Regulation No. 3 of 2011 about Assessment and Handling of Land Disputes, conflicts by definition are a type of land dispute that has significant socio-economic impacts.

In Riau Islands Province, the disputes arise among locals or between local communities and other parties, i.e., private companies or governmental bodies because of high demand to occupy strategic land for specific purposes, such as for tourism resorts, harbors or other development projectsIn a coastal area of Rempang Island, Batam Regency, for example, the locals protested over the state's occupation and development planning of six new harbors by private sectors (Dinamika Kepri, 2013). In Senggarang and Madong, a bauxite mining company has created jobs for locals, but it has also caused issues due to improper compensation during the take-over of possession. and caused derivative coastal environmental damages, e.g., mangrove cut-down, damaged fishing ground (Batam Today 2013; Samin et al. 2013). In Kampung Bugis, a coastal village, the bauxite mining waste created high tension between the mining company and the locals (Tanjungpinang Post, 2011). In Kamboja Village, many residents lack land certificates, raising concerns about rights insecurity and environmental impacts (Saputra et al., 2019).

Besides the problem of rights and boundaries determination, there is also a problem of “missing value”, meaning that no legalized and surveyed land value for supporting land administration has been established in most of the coastline settlements using fitted valuation techniques. For taxation purposes, the value is made available in very few coastal settlements near the city center. Unfortunately, as noticed in Kamboja Village, to speed tax collection, the local government uses the value from the neighboring settlements located on the mainland. Although the use of neighboring values is simple, it can be misleading, as those values are derived from the existing land-use-based valuation technique aimed at hinterland areas.

It is also observed that when determining the preliminary zones to put the sample sites and size, the current Indonesian valuation technique uses the land-use polygon as the basis. This technique frequently provides the zones' boundaries that might cross or overlap the parcel's boundary. There are also zones that do not meet the minimum size in some polygons. It is also observed that the system heavily depends on field surveys to gather data samples and conduct interviews, which makes the current system labor-intensive in data gathering (Astutik et al., 2017). The improvement is required, as it is already noticed in research that land valuation in coastal areas presents unique challenges compared to hinterland regions, requiring specialized techniques and consideration of distinct factors (Kara et al., 2018; Saputra et al., 2021)

There will be lost information if the land value has not established appropriately. Without valid land value as a basis for sensible calculation, it is difficult to get fair compensation in land procurement projects and a fair tax rate for the landholders, which may lead to unsuccessful projects and even conflicts. Even so, in Indonesia, once individuals pay Land and Building Tax (*Pajak Bumi dan Bangunan*), the proof of it is recognized by the public as an indirect indication of occupation, which is also useful to increase a bargain in the sale.

A land with proof of tax payment is more secure than one without. Land value is also vital in a mortgage (a process to convey the property to a creditor as security on a loan) because the amount of the loan is also established concerning the value of the property (land and buildings). It means, in a broader sense, the no-value circumstances will make the chance to secure access to the fair condition of land transfer not optimal (Bazoglu et al., 2011).

Table 2. Existing problematic condition of land administration aspects in the coastline areas

No	System	
	Components/Items	**Existing condition for coastline area**
1	Tenure forms rights type	Unclear tenure forms for aquatic land parcels Neglect the local tenure forms
2	Compliance with existing regulation	Tenure forms are unclear, leading to potential regulatory non-compliance.
3	Comformity of tenure with spatial plans/planning zones	Title-rights allocation is vague, with unclear zones and seaward boundaries for rights distribution.
4	Conformity of tenure with physical characteristics/settings	Title-rights allocation for various aquatic land parcels (vacant, built-up, or with permanent structures) remains vague.
5	Spatial boundary of tenure placement in the coastal area	Unclear guidelines on where tenure should be assigned and the geographical scope for tenure arrangements.
6	Subject of arrangement	Unclear to whom the rights should be properly given/who is eligible

Table 2 (continued)

7	Information of Rights, Responsibilities, and Restrictions	Lack of clear identification of rights, responsibilities, and restrictions for aquatic land parcels.
8	Parcel-boundary	Obscure. Dimensions and demarcation are poorly defined for aquatic land parcels.
9	Cadastral objects	Ambiguity over proper cadastral objects in coastal areas
10	Technique for boundary extraction	Over-reliance on terrestrial surveys leads to lengthy and costly processes; underutilization of aerial imagery/photos.
11	Accuracy	Focus primarily on achieving rigorous accuracy, rather than accuracy fit for the specific purpose.
12	Value area	Valuation processes largely target hinterland areas, neglecting the coastline.
13	Valuation technique	Aerial imagery/orthophotos are underutilized for data sources for valuation
14	Value affecting factors	Lack of recognition of value factors unique to coastal settings.
15	Sampling techniques	Sampling is area-based and not appropriately aligned with a rational minimum number.
16	Boundary of value zone	Value zones do not align with parcel boundaries, causing a single parcel to be assigned multiple values
17	Statistical test	Absence of rationality testing in the valuation process.
18	Creation of value zones	Mainly based on existing land use so it actually reflect "use zone" rather than "value zone".

Source: the author's identification

To tackle those situations shown by the table above, we need to implement a proper tenure arrangement (to deal with no. 1 to 7), utilize a responsive cadastral system (to deal with no. 8–11), and conduct a fitted and effective land valuation (to deal with no. 12–18) as tools in land administration using principles and suitable techniques. As an administering mechanism or process, the tenure arrangement will determine and allocate the proper tenure forms (or type of tenure arrangement) in compliance with the existing regulations in land administration and land management as an effort to tackle "tenure confusion". The compliance with restrictions such as spatial planning zonations is crucial as argued by Chigbu et al. (2015) that it can give regulatory certainty of the parcel location in the sense the spot-on position can discourage forceful evictions or avoid displacement. In this case, we may look into the situation that the housings located in the conservation zones or even disaster-prone zones will be more unsecure that the housings located in the residential allotted zone.

Cadastral systems are defined as the technical element of land administration systems that comprise a land registration system and a cadastral survey/spatial recordation as key components (Williamson,1995). A cadastral system can support tenure security because, as argued by Enemark (2004) it has functions to clarify rights and claims through boundary definition and measurement. To be more specific, a cadastral system can support tenure security is due to its functionality to conduct a survey to bring an undefined boundary of the tenure forms into a reliable boundary. A boundary definition is one prerequisite aspect in the titling process. Land valuation can support land tenure security as it can produce land value as an essential instrument to gain further economic benefits, as has been explored in previous paragraphs. By facilitating tenure claims through boundary definition followed by titling process, cadastral systems provide legal/regulatory tenure security (Hessen and Williamson, 1990) while dealing with land valuation the systems support security from an economic point of view.

One approach to instituting those activities (i.e., tenure arrangement, utilization of cadastral system, and land value modeling) is by putting the vision of implementation into practice by taking the concept of fit-for-purpose land administration (FIG and World Bank, 2014). This concept is specifically established for developing countries. It focuses on reducing the tenure security gap with countries that have advanced land administration systems by proposing, first, "methodologies that are most fit for the purpose of providing secure tenure for all" rather than using the conventional or universal methodologies (GLTN/UN-Habitat, 2016, p. 14). "All" here refers to everyone who deserves and every land parcel that is eligible. *Second*, it proposes flexibility on shaping spatial, legal, and institutional frameworks for land administration infrastructure and services (tenure arrangement, cadastral system, cadastres, land valuation and taxation system, land use planning and control) based on the societal needs. Flexibility in this approach takes places in the situation of the most-fit spatial accuracy and standards option when conducting cadastral surveying through aerial/satellite imagery rather than field surveys. Flexibility also means seeing land tenure as a continuum that shows the diversity of tenure in tenure arrangement and flexibility for shaping the frameworks of its systems to best accommodate societal needs (GLTN/UN-Habitat, 2016). *Third*, although initially, it aims to meet the basic need today through an optimal way in balancing cost, time, and accuracy (it means, the issue of high accuracy is not becoming the main issue as in traditional cadastral systems), it also considers that incremental improvements should be undertaken over time. With these characteristics, it is said that FFP promotes and attempt to achieve several elements or criteria that are flexible, inclusive, participatory, affordable, reliable, attainable, and upgradeable systems (FIG and World Bank, 2014).

FIG argues that the fit-for-purpose concept brought good results when implemented for agricultural plots in Rwanda and Ethiopia (GTLN/UN-Habitat, 2016). Bennet and Alemie (2016) assert in their paper that the continuum of land rights is closely linked to the potential for land markets, a potential that is facilitated in part by the provision of land value. However, when there is a necessity to bring this concept into Indonesian settings, and particularly in the shore settlements through tenure arrangement, cadastral system, and land valuation, their format needs to be contextualized, and their operationalization needs to be assessed. It is because, first, land legislation (policies, regulations, and standards) is established following the political structure, cultural situation, and socio-economic drivers in Indonesia, as the legal basis is different. Second, particularly for the cadastral system, some basic cadastral definitions of boundaries are still necessary to be clarified, such as the exact form and location, dimension, and whether demarcation and *contradictoire delimitatie* (i.e., boundary agreement with neighbors) are necessary in accordance with any tenure forms that are applicable to aquatic land parcels. These obscurities are caused by the third situation, where the parcels in the coastline settlements embrace some unique characteristics as a result from the influences of both marine and land environment. As a direct adoption from the existing systems (land-based administration) can be oversimplified, these characteristics are essential to be appropriately addressed to bring the proper tenure arrangement and deliver the "fitted shape" of the cadastral system (when deployed to provide a reliable boundary of tenure) and land valuation modelling (when used to estimate land value). These highlight the need for adapted land administration approaches in coastal regions that account for their unique characteristics and challenges.

Some of the general characteristics are:

- Administrative and regulatory characteristics: dual regime.
  There are two administration regimes in coastal areas: land-based regime and marine-based regime. In the aspect of governing tenure systems, there will be coastal tenure influenced by land tenure and coastal tenure influenced by marine tenure. In the aspect of spatial planning systems, there will be the RTRW from land-based regime and the RZWP3K from marine-based

regime. The existence of this dual system requires a consideration of the restrictions from both regulations.

- The location of the land parcels on the submerged lands.
  Different from ordinary land parcels, the aquatic land parcels are located in shallow waters. In that area, there is a low-tide period when the surface is not covered by water and a high-tide period when the surface is covered by water. Because of this, there are two types of parcels in aquatic lands based on how submerged they are: permanently submerged and temporarily submerged. The process for setting up tenure needs to be different for each type of parcel. In the aspect of land valuation, submerging conditions dictate the model configuration of land value in the area, for example, in the usage of depths as one of the affecting factors.
- Various land utilization.
  In shore settlements, some of the utilizations are durable and connected to water floors, such as housing and restaurants; the others are just temporary and floating, such as "bagan apung"/floating fishing traps and floating gas stations. Therefore, a consideration concerning the type of aquatic land parcels that can and that cannot be given any rights is necessary.
- The settlement morphology.
  Accessibility
  An aquatic land settlement usually has two access points for residents' mobility. The first one is the bridge functioning as the roadside access connecting houses to the mainland, and the second is waterside access, which is typically used as access for fishing activities. Some of the parcels have a direct connection to the mainland by the bridge, while some do not (i.e., sea-locked parcels). These connectivity circumstances define what suitable rights are for the lands and also how a land valuation model is constructed in an aquatic land area because there is a strong correlation between land value and accessibility.
  Building typology
  In normal lands, the appearance of a building is only one indicator of landholding, but in aquatic lands, it is becoming the main indicator of land possession/claim. The other aspect, the building permanence, is also the relevant issue because it is related to the allowed duration of holding aquatic land titles. The more permanent the building, the longer the duration of title rights can be given. Therefore, in tenure arrangement, the building's appearance and permanence are important factors for determining which rights that can be assigned to the people.

Figure 4 shows the conceptual framework of this thesis.

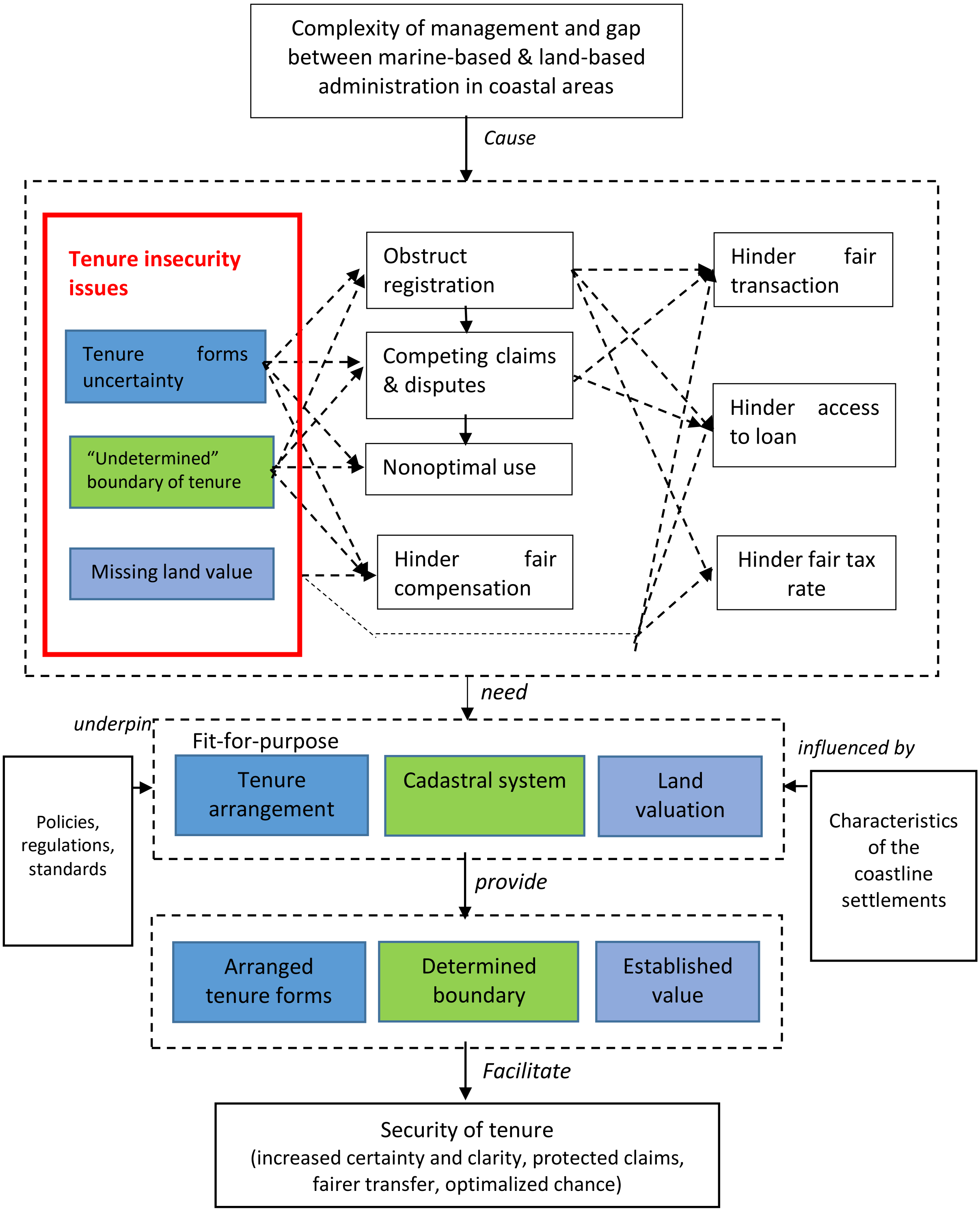


Figure 4. Conceptual framework

1.2 PROBLEM STATEMENT

Based on the abovementioned background, we state the problem statement as follows:

In a circumstance of increasing interests that deliver high occupation demand and competing claims, the vagueness of land administration in the coastline areas of Riau Islands Province, Indonesia, causes tenure uncertainty (legal and spatial: unclear rights and their boundaries) and a lack of proper land value that hinders tenure security. This situation necessitates land tenure arrangement, a cadastral survey system, and land valuation, respectively. However,

considering the distinct characteristics of the aquatic lands that lead to the necessity of establishing context-specific solutions, it remains unclear how tenure forms should be arranged properly, how the cadastral survey system should be implemented accordingly and whether the system will support a fast, cheap, and appropriately accurate boundary acquisition, and how the aquatic land value will be modeled and whether the model attains the required standards.

1.3 RESEARCH OBJECTIVES

Responding to the research problem statement, the general objective is to develop and assess the designed solutions to strengthen tenure security to ensure legal, spatial, and value-based certainty in the coastline areas of Riau Islands Province, one of Indonesia's most prominent archipelago provinces. The study’s specific objectives and connecting research questions are as follows:

1. ***To discover proper tenure arrangement by searching the optimum tenure forms and examining their compliance with spatial plans and physical settings***
    a. What secure situations are preferred by the locals?
    b. Which statutory and non-statutory tenure forms are potentially applicable?
    c. What are the optimum tenure forms, ranked as the trade-off between the preferred secure situation and the potentially applicable tenure forms?
    d. What is the extent of the seaward boundary within which tenure may be granted?
    e. Which are the tenure forms that conform to spatial plans and physical settings?
    f. What are the information of rights, restrictions, and responsibilities should be linked to aquatic land parcels?
2. ***To assess the application of Unmanned Aerial Vehicles (UAVs) for aquatic land tenure boundary acquisition in the coastline settlements***
    a. What are the appropriate boundaries of aquatic land parcels under Indonesian cadastral system?
    b. What is the minimum number of GCPs required to achieve stable accuracy?
    c. Do the produced orthophotos achieve the spatial accuracy required for cadastral base map?
    d. Is the UAV operability fit-for-purpose in terms of duration and cost?
    e. How close is the general boundary from semi-automated feature extractions to the reference boundary in terms of completeness, correctness, and quality?
3. ***To develop and assess aquatic land valuation in the coastline settlements***
    a. What are the relevant affecting factors of aquatic land value?
    b. How the land value is modeled (what are the principles of land valuation for aquatic land parcels in the study area?
    c. How is the distribution of land value in the study area?
    d. How good is the performance of the valuation?

1.4 RESEARCH METHODOLOGY AND ACTIVITIES

This research reaches the objectives by setting up approaches and operational stages. The approach is a mixed-method: combination of qualitative and quantitative analysis. The qualitative or descriptive study sections primarily focus on exploring potential tenure forms and providing context for the aquatic land cadastral system. We used quantitative analysis to assess the operability of the cadastral system, multi-criteria decision analysis, land value modeling, and their measurable performance. The linkages among objectives, research questions, methodology, and expected results are presented in the research matrix (Table 3).

The research comprises three operational phases (Figure 5). The first phase is a review phase, which included topic development, literature and document review, and preparation for fieldwork. In the second phase, which is a mix of the fieldwork and analysis phases, the principles and frameworks of aquatic land tenure arrangements, cadastral systems, and land valuation were developed. This was done with a focus on the fit-for-purpose land administration approach. The fieldwork was conducted to obtain primary and secondary data. The first stage of fieldwork collected primary data through questionnaires, interviews, and field observations, and secondary data through the authorities via online or office visits. The field observation provided information about the existing informal tenure forms, land parcel attributes to be used in land valuation modeling, and insights about the characteristics of the coastal settlements. At the same time, this thesis also analyzed and structured relevant data and information to define the aquatic land tenure arrangement and land valuation principles and frameworks. The questionnaire surveys yielded valuable insights into the locals' preferred tenure security situations. After that, we conducted the second stage of fieldwork, which was an execution stage of field data acquisition for UAV-based cadastral surveying (UAV flight, GNSS/GPS survey for GCPs and ICPs) and land valuation survey (land price and other attributes collection).

The last phase is an analysis phase and thesis writing phase. There are three analyses in this phase: tenure arrangement, cadastral survey performance, and land valuation modeling and performance analysis. Tenure arrangement part, which included a multi-criteria analysis (AHP and Fuzzy TOPSIS), aimed to obtain the optimum tenure forms and proper tenure arrangement. The legal-based optimum tenure forms have come as a resultant of the preferred secure situations and the potential tenure forms from customary and statutory governing systems. Tenure allocation, following the spatially based tenure allocation principle, had a goal to assign those rights suitably following some relevant considerations and restrictions. In the cadastral system performance analysis part, we conducted accuracy and survey management analysis of the UAV survey and mapping. RMSE analysis was used in the accuracy analysis to check how reliable the UAV orthophoto is as a cadastral base map and as the source of the land parcel's boundary. Survey management analysis was mainly based on relevant fit-for-purpose criteria. In aquatic land value modeling, we defined the affecting factor and developed a technique of comparison scoring, which then controlled and tested the quality using statistical analysis (multiple regression analysis) and conducted an evaluation using relevant criteria from the fit-for-purpose approach. Finally, the findings, discussion, and recommendations are presented in the thesis report.

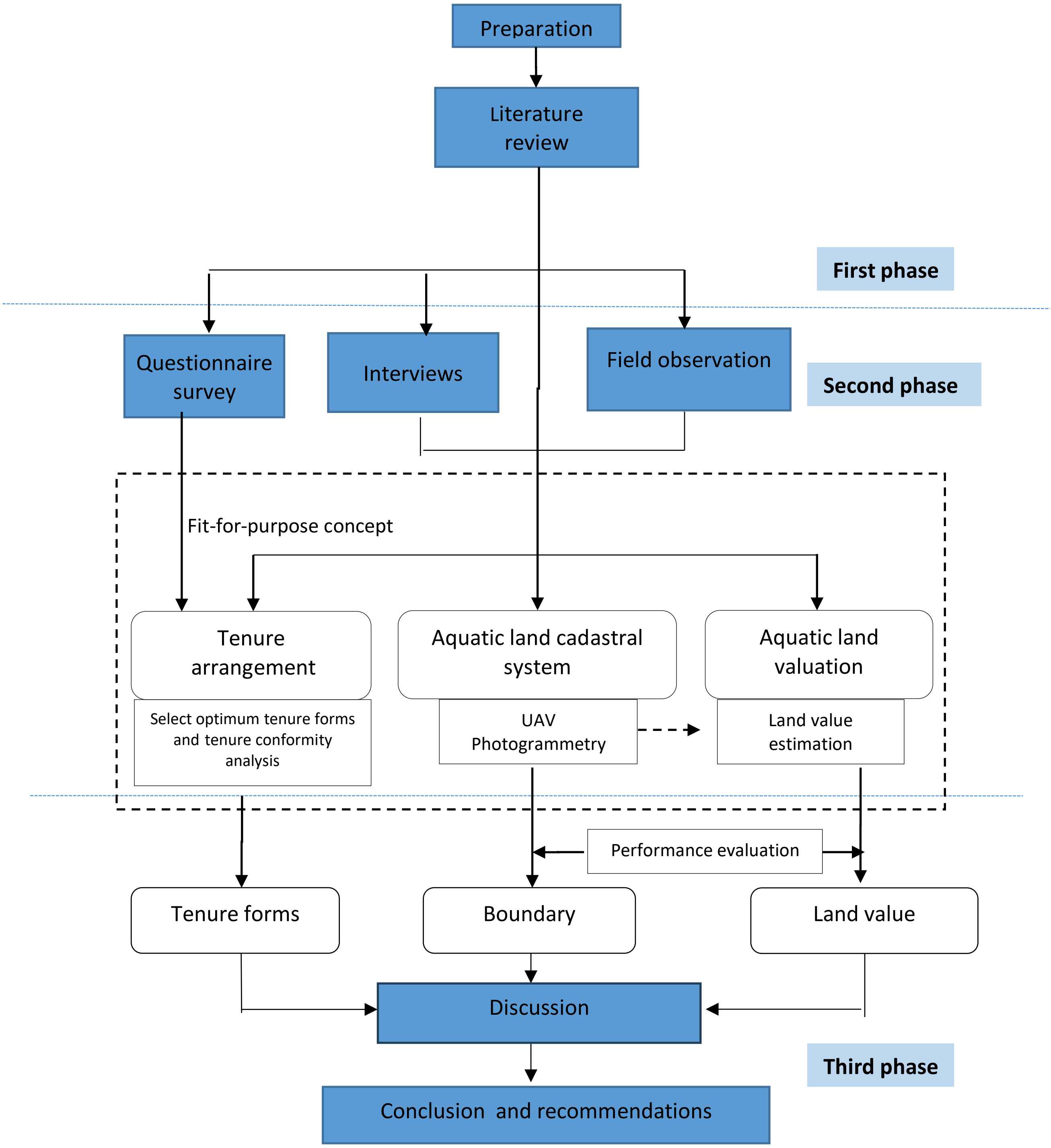


Figure 5. Sequence of research flow

Table 3. Research matrix

Objectives	Questions	Methodology	Results
1. To discover proper tenure arrangement by searching the optimum tenure forms and examining their compliance with spatial plans and physical settings	a. What secure situation is preferred by the local? b. Which statutory and non-statutory tenure forms are potentially applicable? c. What are the optimum tenure forms, ranked as the trade-off between the preferred secure situation and the potentially applicable tenure forms? d. What is the extent of the seaward boundary within which tenure may be granted? e. Which are the tenure forms that conform to spatial plans and physical settings? f. What are the information of rights, restrictions, and responsibilities should be linked to aquatic land parcels?	*Data and information:* Literature, policies, regulations, field notes, preference of the locals about secure situation *Methods:* ▪ Literature review of tripartite view of tenure security, coastal spatial planning, and the related regulations ▪ Field observation and discussion to gain information about informal tenure, physical characteristics ▪ AHP questionnaire survey for obtaining data about preference of the locals about secure situation ▪ Multi-criteria analysis (AHP and Fuzzy TOPSIS analysis) ▪ Heuristic assessment and descriptive-qualitative analysis	▪ Identification of informal tenure forms ▪ Identification of potential formal tenure forms ▪ Preferred secure tenure situation ▪ Optimum tenure forms and ranking ▪ Defined seaward boundary, allotment zones, and settings for allocating tenure for aquatic lands ▪ Framework for tenure arrangement ▪ Identification of entitlements and considerations of tenuring lands
2. To assess the application of Unmanned Aerial Vehicles (UAVs) for aquatic land tenure boundary acquisition in the coastline settlements	a. What are the appropriate boundaries of aquatic land parcels under Indonesian cadastral system? b. What is the minimum number of GCPs required to achieve stable accuracy? c. Does the produced orthomosaic achieve the spatial accuracy required for cadastral base map? d. Is the UAV operability fit-for-purpose in terms of duration and cost? e. How close is the general boundary from semi-automated feature extractions to the reference boundary in terms of completeness, correctness, and quality?	*Datasets:* ▪ GCPs, ICPs, UAV raw photos *Methods, techniques, measures:* ▪ UAV fixed-wing survey (Structure from Motion for orthophoto generation) ▪ GNSS-geodetic static survey for control points acquisition ▪ On-screen digitation and semi-automatic approach for boundary acquisition ▪ Measures for performance assessment: ✓ RMSE and CE analysis for reliability (spatial accuracy) and optimum scale analysis. ✓ Completeness, Correctness, and Quality measures for the extracted boundary ✓ Duration, affordability/cost *Instruments:* ▪ UAV fixed-wing Skywalker t-tail with Sony QX10 18MP, telemetry standard up 15 km for image acquisition	▪ Ground Control Points (GCPs) and Independent Control Points (ICPs) ▪ Optimal number of control points to produce reliable imagery ▪ UAV orthophoto ▪ Geometric accuracy analysis results ▪ GIS-generated boundaries ▪ Appropriateness of the orthophoto as a base map ▪ Description of the advantages and limitations of the system ▪ Defined aquatic land cadastral boundary ▪ Proper method for boundary acquisition ▪ Suitable area for implementation of the method

Table 3 (continued)

		▪ Trimble GNSS Receiver NetR9 and R4 (Base and Rover) for control points survey *Specific software:* ▪ Agisoft Photoscan Professional for aerial image processing ▪ Mission Planner to arrange flight planning ▪ Trimble Business Center for control points calculation ▪ ArcGIS for geospatial datasets creation and visualization, and Object-based Image Analysis (OBIA) for building boundary extraction ▪ Pre-trainined Artificial Intelligence Mapflow.AI in QGIS for building boundary extraction	
3. To develop and assess aquatic land valuation in the coastline settlements	a. What are the relevant affecting factor of aquatic land value? b. How the land value is modeled (what are the principles of land valuation for aquatic land parcel in the study area?) c. How is the distribution of land value in the study area? d. How good the performance of the valuation??	*Datasets:* ▪ UAV orthophoto as material to get the preliminary zone to determine the minimum sample size. ▪ Parcels samples from data collection and its attributes *Methods, techniques, measures:* ▪ Field observation and GIS to produce data for valuation ▪ Comparison-score parcel-based mass valuation ▪ Multi-regression analysis *Instruments:* ▪ GPS handheld for recording the representative coordinates of the parcels during data collection *Software:* ▪ ArcGIS 10.3 to conduct spatial data extraction and manipulation, land value visualization ▪ SPSS for statistical analysis	▪ Land value map ▪ Proper factors for valuing aquatic parcels ▪ Significant value variables ▪ Performance of the model/goodness of fit value of the model ▪ Aquatic land valuation principles ▪ Description of the advantages and limitations of the valuation technique

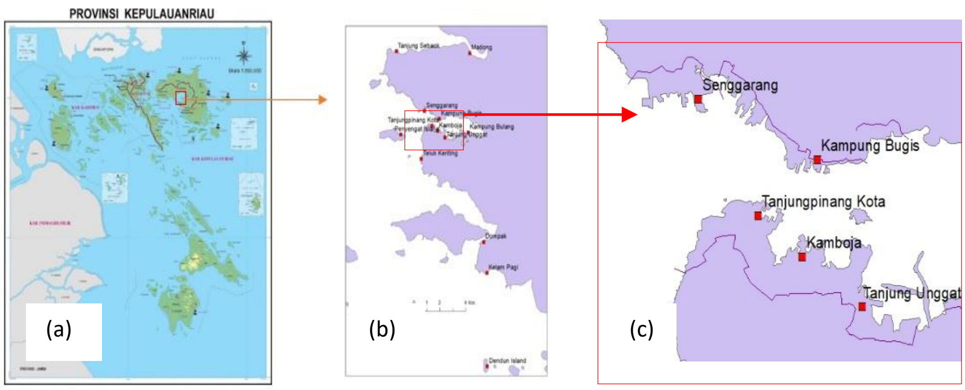
1.5 RESEARCH AREAS

The research is located in selected shore settlement areas around Tanjungpinang (Figure 6). The characteristics of those settlements are typical in Riau Islands Province.

a. Tenure arrangement study that requests the questionnaire input from the local residents covers 13 settlements (see Table 4). Those areas are known to have tenure insecurity histories (such as land disputes, land acquisition for coastal development, or threats from illegal bauxite mining).
b. Considering more intensive primary data exploration and technical works, the UAV cadastral survey is located in fewer settlements (five settlements, ± 400 hectares).
c. Land valuation is located inside the area of the UAV survey (4 adjacent settlements, ± 200 hectares). The exploit of UAV products for extracting some influencing value factors and the availability of property market price would be the reason for this.

Table 4. Research areas with regard to the topics

No	Settlement location	Tenure arrangement study	UAV-based cadastral survey	Land valuation
1	Tanjungpinang Kota	✓	✓	✓
2	Kamboja	✓	✓	✓
3	Tanjung Unggat	✓	✓	✓
4	Senggarang	✓	✓	
5	Kampung Bugis	✓	✓	
6	Teluk Keriting	✓		
7	Kampung Bulang	✓		✓
8	Tanjung Sebaok	✓		
9	Madong	✓		
10	Penyengat Island	✓		
11	Dompak Darat	✓		
12	Klam Pagi	✓		
13	Dendun Island	✓		



a) Tenure arrangement b) UAV cadastral survey c) Land valuation

Figure 6. Study areas

1.6 CONTRIBUTION AND SCOPE

Under the whole idea of supporting land tenure security for the coastal area of Indonesia, this research attempts to contribute to some specific aspects as described in the following statements:

CONTRIBUTION

Developing a proper tenure arrangement

Enrich the spectrum, establish parameters of a secure tenure situation, and tackle tenure confusion from the spatial planning perspective

Although not as abundant as on land, research about tenure in the Indonesian marine environment is not rare in the literature. Take examples, there are past studies about a tenure called *seke* in North Sulawesi (Mantjoro and Akimichi, 1996), *rompong* in South Sulawesi (Satria et al., 2002), *sasi* tradition in Maluku (Wahyono et al., 2000), *sasi* tradition in Raja Ampat Papua (McLeod et al., 2009), *petuanan* tradition di Haraku Maluku (Hernandi et al., 2014), and *awig-awig* and *sawen* in North Lombok (Satria and Adhuri, 2010). However, those studies are about managing fishing grounds on a large scale and do not entirely fit with the tenure occurring in coastline settlements, which also encompasses small-scale tenure. It is also noticed that the tenure in the aquatic lands could be differentiated to some degree from marine tenure by taking into account the concept of separation between deep sea and coastal shallow waters (Tamtomo, 2004). This study puts the tenure analysis within the perspective of land tenure security, such as from the frame of tripartite view of security (Van Gelder, 2009; and Hollingsworth, 2014). It is about answering our inquisitiveness: what are the deliverables of the form regarding the tenure security degree it can provide, or do the identified tenure forms meet the preferred criteria of tenure security of the locals and at the same time meet the regulations of tenure arrangement? Therefore, when a study from Sofyan (2016), Puslitbang BPN (2010), Tamtomo (2006) descriptively analyzed the potential tenure forms only from the regulations point of view, this research extends it by incorporating the residents' perception about secure situation they consider essential for them, and then combines it with the regulations demand through a multi-decision criteria analysis. The involvement of the questionnaire survey to elicit perceptions and provide what kind of tenure security the locals prefer for their aquatic land parcel will reveal the on-the-ground needs. By going further into conformity assessment (which is also not investigated by Tamtomo and Puslitbang BPN) the study goes deeper to tackle tenure confusion from the spatial planning perspective. Shortly, with this analysis, the research attempts to enrich the spectrum of tenure profile and tenure arrangement literature in Indonesia.

Recommendation for land registration system: Providing the best practice for boundary acquisition of aquatic land parcel through UAV-based cadastral system and semi-automatic boundary extraction

In land administration discipline, this study aims to provide literature about cadastral system in coastal areas. Research about cadastral system implementation in inland areas are abundant, but such studies are limited in coastal areas of Indonesia. Although Tamtomo (2006) had studied cadastre for marine environment in Indonesia, his study focuses more on public policy. Abdulharis et al., (2008) concentrate on stakeholder analysis of marine cadastre (which also more in sea-environment than to the coastal-waters environment). Their studies also do not investigate detailed themes about some cadastral principles, such as boundary definition and surveying—the topics that this study pursues.

In Indonesian land administration system, the cadastral system works for formal land tenure. By sorting which statutory tenure forms can be given by the government (as part of the tenure arrangement analysis), to which cadastral objects (parcels), to whom, and at where, this research attempts to clarify vague title-rights allocation (Indonesian: "pemberian hak") in the coastline areas, the area that has been neglected in terms of land registration service in Indonesia. In practice, the study will contribute to the improvement of the current Indonesian cadastral system.

This attempt, together with the proposed boundary definition of cadastral objects in the study area, would help to avoid confusion about how land registration should be established in the shore settlements. The recommendations support Ministry for Agrarian and Spatial Planning/National Land Agency (ATR/BPN) to complete its target to register all land nationwide, facilitating tenure security for all: for the ones who deserve and on any lands eligible. Statistics show that until 2017, around 55,4 million parcels of 97,2 million are still not registered (Dzihrina et al., 2017). The number is still excluding land parcels in the shore settlements, which means the actual target is bigger than that.

Land registration in Indonesia is much relied only on ground measurement or terrestrial surveys for cadastral boundary data acquisition, and thus resulted in low cadastral coverage, long duration, high demand of human resources and high cost (Dzihrina et al., 2017). This calls a driver for an innovative way that can expedite the mapping process, and provide low-cost and scalable mapping solutions (Luo, et al., 2017) and Silalahi et al. 2014. As recommended by fit-for-purpose approach, this research utilizes a non-terrestrial UAV-based cadastral survey to produce orthophotos, that will be used as medium to conduct boundary measurement as the part of boundary determination activity. As a technology that is growing popularity, UAV has the potential to be an effective means to support adjudication purposes, generally in agricultural, border areas, and inland urban areas as shown by, for example, Barnes et al. (2014), Ramadhani et al. (2018), Silalahi et al., 2021) and Mumbone (2015). This research will look on its usage in the different area: the coastline settlements, carry a proper framework, and deliver knowledge about its product reliability for this particular area. By also testing a semi-automatic feature edge mapping technique for detecting, extracting, or reconstructing visible boundaries through Object-based Image Analysis (OBIA) from a commercial software and pre-trained Artificial Intelligence (AI) from free and open source software, as patterns or objects, from representations of physical objects in imagery or point cloud data - which those previous research did not incorporate – we attempt to deliver an understanding whether this technique can perform well to support a development of more automated image-based cadastral survey approach for fast land registration in coastline areas. Therefore, the goal is to develop the foundations for a best practice semi-automated approach, for extracting tenure boundary of aquatic land parcels from digital orthophotos.

Developing land value estimation specific for the settlement in the coastline areas

In valuing aquatic land parcels, this research develops land value estimation model that incorporates cadastral and spatial datasets supported by UAVs, together which other relevant affecting factors of land value built from identified characteristics. The contribution is located on the determination of the specific affecting factors and framework different from the ones that have generally done for ecosystem valuation or for Indonesian upland parcels valuation (Directorate of Land Valuation, 2014), to help the authorities establishing a more specific valuation for aquatic land residential area. By running regression modeling, we also aim to have an rationality test of the model.

General contribution

Indonesia has eight archipelago provinces as in Figure 1. It makes no difficulties to find similar aquatic land settlements with different names. For instance, there exist what has been called as Floating Houses Deli (Bagan Deli) in Medan North Sumatra, Kampung Seberang Gantung of Sawang People in Bangka Belitong in Sumatera Island, Kampung Nelayan Duano ethnic group in Kuala Tungkal, Jambi Province. The other examples are Sea Village (*Kampung Laut*) in Balikpapan, East Borneo, Floating Village (*Kampung Apung*) in Batu Ampar West Borneo, and Floating Settlement (*Pemukiman Apung*) in Muna Island, Southeast Sulawesi, Bajao Housing (*Rumah Bajo*) in Togean, Central Sulawesi, just mention few of them. This research results can be a lesson learned. To some extent, apart from the existence of local tenure forms that are always unique in each area, the principles and techniques could be adapted to the other aquatic areas because they are basically developed within the context of national land administration system.

Scope

The study identifies and examines the existing local coastal tenure forms in the study area, as one of the analysis part without an exploration in detail, for example, about sociological settings, power relation, and contestations, because those are not part of the objectives. In general, according to Sari (2010), a cadastral system comprises of two parts: process/activities and data (information management). In line with the research problems and our focus about addressing land tenure insecurity from the aspect of the provision of proper rights arrangement, well-defined boundary, and determined value, the assessment of the cadastral system utilization occurs only on its process/activities part namely cadastral surveying (and its related aspects such as land parcel boundary definition). The other elements, such as land parcel information management and information system, which is about cadastral data modeling, storage, and retrieval system, networks and database design, data catalog, and sharing mechanism through Spatial Data Infrastructure (SDI) are out of topic. In Indonesian land administration system itself, under the Ministry of Agrarian and Spatial Planning/National Land Agency (ATR/BPN) Letter No. 5/SE-100/I/2015 about Utilisation of Computerised Land Activities and Programmes, since 2015 there is an established integrated information system named GeoKPP (Geo-Komputerasi Kegiatan Pertanahan or Geo-application for Computerized Land-related Activities). Therefore, we put the matter about land information system and management under the GeoKPP and do not explore it further.

The utilization of the aquatic land cadastral system in the boundary survey and the valuation of aquatic land will only focus on the built-up area in coastal areas which are the shore settlements and will exclude the other areas in coastal waters environment, such as coastal forests, tourism sites, marine protected areas, large fishing grounds or breeding areas. In tenure conformity section, this thesis still includes these areas because in the spatial planning system, those areas also listed as spatial zones, and one of few ideas behind this tenure arrangement analysis is attempting to find the compliance of the tenure forms with all zones in the systems.

The setting of stakeholders (i.e., administration tasks from the involved governing bodies and their different roles) of the tenure arrangement, cadastral system services, and land valuation system in Indonesian coastal areas will not be specifically analyzed in this research. It means this research will not include the institutional arrangement of public policy in administering aquatic lands. However, we will use the institutional products of those bodies (e.g., laws, regulations, technical standards) in our analysis.

1.7 Working steps and thesis structure

This thesis is organized into six chapters to present the research works. The first chapter serves as the introduction, the second chapter functions as the revisit and review of used concepts, the following three chapters provide the working and technical reports, and the final chapter functions as a reflection and wrap-up section.

Chapter 1: Introduction aims to deliver the research background about the existing problematic conditions linked to the geographical setting of the coastal land administration in Indonesia and the study area in Riau Islands. The chapter then denotes the research problem, the research motivation, and the research gap the thesis seeks to fill. A general overview of the research objectives, methodology, and activities will also be presented, together with the expected contribution within the scope of this research. To put the works into theoretical context and framework related to the discipline of tenure security, land administration, and valuation, in **Chapter 2: Definitions and concepts**, we present and discourse some general and fundamental concepts and the developed fit-for-purpose land administration approach as a theoretical lens when we advance the operational framework and methods for the next three working chapters.

Chapter 3: Tenure arrangement is intended to report our activities in seeking and establishing adapted tenure arrangements in coastal settlements. As the analysis chapter, the section presents our identified potential tenure forms. This chapter is important to bring the compiled wish list of secure situations from the literature and the questionnaire survey, the preferred secure situation to accommodate the communities' view using Analytic Hierarchy Process (AHP) analysis, and finally the most suitable forms to be applied in coastal settlements from Fuzzy TOPSIS analysis with input from AHP weights. Besides that, using qualitative descriptive analysis, the chapter also assesses the tenure forms conformity with geographical settings, the adherence of suitable tenure to spatial plans, and their alignment with the physical characteristics of shore settlements. Additionally, this chapter also reveals our literature investigation to acquire the rights, restrictions, and responsibilities information that should be associated with aquatic land parcels, pursuing the concrete attribution of this crucial information in guiding aquatic land settlement utilization and services.

Chapter 4: UAV System for supporting aquatic land cadastral boundary acquisition is critical to show the work to address tenure insecurity from spatial dimension of the land. This section delves into the application of Unmanned Aerial Vehicle (UAV) technology for acquiring accurate and up-to-date cadastral boundaries in aquatic land settlements. It outlines the specific steps involved in the UAV survey process, from vehicle selection and flight planning to image processing and boundary extraction. A key focus is on the validation and reliability of the extracted building footprints and boundaries, assessing both the accuracy of the UAV-derived data and the operational efficiency of the system. By employing advanced image processing techniques, object-based image analysis (OBIA) and Mapflow.AI, a pre-trained artificial intelligence technique utilizing Mask R-CNN (Mask Region-based Convolutional Neural Network), this chapter aims to demonstrate the potential semi-automatic approach of cadastral mapping in challenging coastal environments.

Chapter 5: Land value estimation is the third empirical chapter and aims to present our land valuation work. A definite land value is essential for establishing tenure security, complementing legal and spatial certainty. This chapter seeks the sound and relevant factors from economics, law, social, and physical aspects that serve as valuation variables by looking at literature and previous valuation studies and taking into account the coastal characteristics of the valuation location. In this chapter, we aim to develop a land valuation technique suited to the characteristics of coastal settlements in the study area and adhere to a spatial framework of a fit-for-purpose approach, making use of GIS-based analysis and aerial orthophoto as the main data source. Our work to establish and use a comparison-score technique of parcel-based mass valuation, deploy a multiregression analysis to test the rationality of the model, and map the value distribution are presented in this chapter.

Chapter 6: Discussion, conclusion, and recommendations as the final chapter provides the summary of the research results, reflecting on its contributions to derive proper land information as a key material in securing land. The chapter discusses the strengths, weaknesses, opportunities, and threats of the approaches, considerations, techniques, and tools used within the context of tenure arrangements, cadastral systems, and land valuation. The conclusion section of this chapter provides a summary of the research findings and their alignment with the objectives. This chapter also delivers our recommendations based on the study's findings for a protocol for arranging tenure in the coastal settlements, practical steps for developing techniques, and future research directions.

2 DEFINITIONS AND CONCEPTS

This chapter provides concepts and operational definitions to facilitate a better understanding of the specific terms used throughout this thesis

2.1 LAND

There are several different meanings about land in the literature. Dale and McLaughlin (1999) define land in a broad meaning as the surface of the earth, the material below, the air above, and all things attached. This understanding is in line with the definition of the Ad Hoc UN Group of Experts on Cadastral Surveying and Land Information in Henssen (1995) stating that "land is an area of the earth, water, soil, rocks, minerals, and hydrocarbons beneath or upon it and the air above it. The term land embraces all things which are related to fixed area or point of the earth, including the areas covered by water, so including the sea".

Some specific areas are also associated with land, such as submerged lands, tidal lands (tidelands), shorelands (coastline areas), wetlands, inland areas, lowlands, uplands, and hinterlands. Submerged lands are land that is under the water, whether permanently or only part of the time (Peters, 2015). The temporarily submerged land is commonly known as tidelands. Ivey (2005) calls submerged lands, which may include shorelands, tidelands, harbor areas, and other navigable waters, as aquatic lands. Wetlands are areas "where water covers the soil, or is present either at or near the surface of the soil all year or for varying periods of time during the year, including during the growing season" (EPA, 2018). While submerged lands specifically indicate the area in the coastal areas, a wetland refers to an area in the coastal area or in the inland regions, with a particular correlation with plants growing in it. Inland areas is a term to define the areas that are not on the coast or along the coastline. Lowlands are an area of low, flat land. In the opposite, there are uplands, which denote land located in higher areas. Hinterland areas are sometimes interchangeable with inland areas since this term also points to the land behind the coast. However, it also shows the areas behind the riverbanks and the areas that are far and remote from the coast.

In Indonesia, a definition from BAL Article 4 defines that land is the surface of the earth, both on land mass and underwater, including space above and underneath, within certain boundary systems (natural, administrative, or by tenure and use). Act No. 24 of 1992 about spatial planning explains that the land can be defined as space, namely land-space (or "ruang daratan" in Indonesian), as a distinctive term from sea-space ("ruang laut") and airspace ("ruang udara"). Land space is a space of the landmass that has borders with sea space in the low tide line. Perangin-angin (1994) denotes that the areas influenced by the land-based utilization activities are considered land. This definition matches the previous concepts stating that the areas along the coastlines (submerged areas, tidal areas) that are still affected by any undertakings from land side, also called land.

Juridically, land is often referried to as a parcel (or plot) of land, especially in the context of land tenure, cadastral system, and land registration. A parcel is a spatial unit of land with particular ownership, use, or characteristics (Dale and McLaughlin, 1999). Donelly (2014) explicitly describes land as a physical form of tenure that owners and their heirs can hold indefinitely. Donelly implied that land can be regarded as a bundle of property rights. With regard to Donelly's view, there are three main categorizations of land in Indonesia:

1. State lands, which comprise free state lands and non-free state lands (Santoso, 2010). Non-free state lands are the lands governed by the state, through other parties that manage or utilize the land and gain certain legitimation on it given by the government. In this category, forest lands, harbor lands, and mining lands can be the examples. The lands outside non-free state lands are free state-lands and through a particular mechanism called "pemberian hak" or granting rights mechanism, those lands can be possessed by the interested parties.

2. Private lands, or in Indonesian term: “land with rights”, and the type of rights should refer to Act No. 5 of 1960 about Basic Agrarian Law (further called BAL).
3. Customary lands. These lands can be differentiated into 1) communal lands or “tanah adat,” which means lands occupied by local communities, based on adat laws-adat tenure system, and 2) traditional and local lands based on traditional and local tenure forms such as *Girik*, *Letter C*, *Petok D*, *Surat Swapraja*, etc.

Based on those insights, this thesis reckons that:

1. As a physical entity in terms of topography and spatial nature, generally, land refers to the earth’s surface, together with everything beneath and above.
2. Nevertheless, land can also be viewed as a space that encompasses all the properties and elements linked to it. The land space is different from sea space and airspace.
3. Land can be defined as "non-sea regime" if used in geographical contexts such as sea-based regimes and land-based regimes.

This thesis will consider the term “land” in an operational definition as the earth's surface, which also includes shallow water-covered land that has a legal arrangement on it. In the context of cadastre and land registration, the thesis will use the term interchangeably with a plot or parcel in connection with tenure and its boundary.

2.2 LAND TENURE

2.2.1 Land tenure arrangement

Land tenure, derived from the Latin *tenere* – to hold (Simpson, 1976) can be defined as “the mode of holding or occupying land” (Zeverbergen, 2002). FAO (2002, p. 7) describes land tenure as the “relationship, whether legally or customarily defined, among people, as individuals or groups, with respect to land’. Henssen (1995, 2010) denotes shortly that land tenure is a man-land relationship. Payne and Lusserve (2002) explore this further by stating that land tenure systems are a product of historical and cultural factors, and they reflect the relationships between people, society, and land. Payne’s definition is in line with a definition from Barry (1999) that says land tenure is a matrix of social and legal relationships. The relationship, in any format, is generally understood as “rights”.

Based on the places where the tenure exists, tenure normally can be separated into marine tenure and land tenure. Following societal needs, the categories then are extending into some new terms such as forest tenure (FAO, 2014), urban land tenure (Doebele, 1987; Payne; 1997), coastal tenure (Cambers et al., 2003), shoreline tenure (Cohen et al., 2024). FAO (2002) further describes land tenure as an institution, in a meaning as invented rules by societies to “define how property rights to land are to be allocated within societies” (p. 7). Hence, based on the governing systems, land tenure comprises informal and formal tenure. Informal land tenure is tenure in which land administration and rules of land and resource use are defined and governed traditionally and commonly in accordance with existing customary norms and value systems or with social/family/religious systems (Reda, 2014). Formal tenure, also called statutory tenure, relies on the formal systems based on written legal policies, regulations, and proclamations put in place by the governments. It does not need to have roots or originate from society. The rights are introduced by regulations into the society. Dale and McLaughlin (1999) and FAO (2002) view land tenure from a general perspective based on how the land is held. FAO states that land tenure systems “determine who can use what resources for how long, and under what conditions” (p. 7). According to this view, there are four categories, namely private, communal, open access, and state tenure.

Private tenure means “the assignment of rights to a private party who may be an individual, a married couple, a group of people, or a corporate body such as a commercial entity or non-profit organization” (FAO, 2002, p.8). Under this tenure, individuals may have exclusive rights to the land parcels and all their attachments, and other parties can be excluded from using these properties without the consent of those who hold them. Communal tenure denotes “a right of commons may exist within a community where each member has a right to use independently the holdings of the community" (p. 8). In this type, non-members of the community are excluded from using the common areas. In an open access tenure, no specific rights are assigned to anyone, and no one can be excluded. This type can appear in open sea and rangelands. In state land tenure, some authorities in the public sector assign the property rights. For instance, the state may hold forest lands in the forestry sector.

Agwey et al. (2015) point out that tenure arrangement refers to how land tenure is organized by the existing governing systems (i.e., statutory and customary tenure). Hence, the arrangement may be in the form of freehold, leasehold, leases, easements, etc. Quaye et al. (2014) view it as how the land shared among people within the existing systems.

There are four main types of tenure structure based on the arrangement, or the mode of how land is held, that can be assigned to relate people and their land: title-based tenure (or in Indonesia also called "rights"), permit-based tenure ("permits"), letter-based tenure ("letters"), and oral-based tenure ("oral agreements"). Those structures emerge in various tenure forms across Indonesia. Tenure forms in this research mean the specified and actual form of tenure arrangements that occur following the tenure governance systems. While often used synonymously with "rights," the term "tenure" in this thesis encompasses more than simply legally recognized land titles. When referring specifically to "rights" as documented in land titles, this will be explicitly stated.

Following a thought from Sutaryono (2015, 2016) in Indonesia, tenure arrangement is viewed wider and more on the regulative perspective, which means the process to regulate of land possession, which involves both rights identification and rights compliance with some considerations and restraints. In Indonesia, this term is established under the scheme of "P4T arrangement", which denotes "Penataan Penguasaan, Pemilikan, Penggunaan, dan Pemanfaatan Tanah" or can be freely translated as "land possession, land ownership, land use, and land utilization arrangement" following the mandate from a Decree of People's Consultative Assembly No. IX of 2001 about Agrarian Reform and Natural Resources Management.

According to Government Regulation No. 16 of 2004 about Land Use Management, the term land ownership is not entirely similar to land possession. Land ownership is a land possession that is more clear and definitive, understood as a kind of freehold tenure that is already established by land titles, which means the term land ownership always refers to the most formal land tenure arrangement. Land utilization is a particular activity on certain land use with the purpose of gaining more benefit of the land. An example of this is the utilization of a house building in a residential area as a house-shop (or in Indonesia called "ruko"), or the utilization of a plot of land in a vast bare land as a fishpond.

This research will have an operational definition of land tenure arrangement as the arrangement of any identified existing relationship between people and land (tenure forms) in compliance with some considerations and restraints (especially spatial planning as the ultimate representative of land use control and management) within the applying statutory and customary governing systems.

2.2.2 Land tenure security

This thesis has briefly described the definition of land tenure security in the Background section. However, for convenience, those definitions are written again in full quotation. IFAD (2015) defines the concept of tenure security as "people's ability to control and manage land, use it, dispose of its produce, and engage in transactions, including transfers" (p. 1). Under this definition, the power possessed by the landholders is becoming the main aspect. AUC-UNECA-AfDB as cited in Bazoglu et al. (2011, p. 5), remark that security of tenure "refers to the degree of recognition and guarantee of rights (including ownership, use, manage resources, lease) that provides protection against forced evictions; the possibility of selling and transferring rights through, for instance, inheritance; mortgage options; and access to credit under certain conditions". From this definition, the perspective is ranging from a human-rights based aspect to the economic aspects.

From those definitions, we may take notes that land tenure security, as an intangible construct, can be sensed in several interlinked notions: (1) clarity, (2) legitimacy, (3) protection from eviction, and (4) ability to utilize and sell (transferability), opportunity, and guarantee for getting future benefits. Clarity is considered as the notion of security which comes from the no-doubt and clear situation regarding the holding. Legitimacy comes from the recognition from others, including the authorities and the neighbors. Protection from eviction is the conservative notion of security, but it is still the most straightforward expression of a secure situation (Reerink & van Gelder, 2010). Whenever the landholders are protected from being evicted, the relationship between the landholders and their land is secured. The notions regarding usability, transferability, opportunity, and future benefit concepts are follow-up concepts of security, derived from the broader perspective of security, which incorporates economic aspects.

Together with those concepts, there is also another perspective concerning a view of land tenure security in a thorough way. Van Gelder (2010b) describes the tripartite view concept of land tenure security, which are de jure security (legal tenure security), de facto security, and perceived security. De jure security focuses on legal dimensions in protecting land ownership. Security of tenure derives from the fact that the right to land is underwritten by a known set of legal rules (Durand-Lasserve, 2006) that "respect for rights and the possibility of their enforcement by the state in case of violation". This perspective considers legal status and formality backed up through legal documents provided by the authorities as proof of recognition as the idea of security.

De facto security focuses on the actual situation, regardless of the legal status, of the land. Meaning, this view considers the factual recognition of the existence of the settlement. The type of security can come from intrinsic characteristics such as the length of time of landholding, the vastness of the settlement, the level and cohesion of the community (Payne, 1997; Durand-Lasserve, 2006). Besides the intrinsic aspects, the secure situation can also be derived from extrinsic factors such as service and infrastructure supports (e.g., development of roads and public facilities, electricity and clean water supply) and the recognition and acceptance from the social, cultural, political, and administrative environment, regardless the provision of written legal status (Durand-Lasserve and Selod, 2007).

In a perceived security situation, Van Gelder (2010b) draws that the idea of how secure or how insecure is coming from the perception of the dwellers. The perception is subjective, could be based on an individual's experience or knowledge of his tenure situation, and or in the scenario of the situation/probability of being evicted or losing land. Van Gelder calls this perception as "a feeling state (the insecurity feelings of a dweller towards his tenure situation) and a thinking state (the perceived probability of eviction)" (Van Gelder, 2007). Although the perceived security has a separate construct from de jure and de facto, for example, in terms of subjectivity, according to Hollingsworth (2014), by incorporating it into the concept, it will enrich the assessment of tenure security. Van Gelder (2010b) even emphasizes that tenure security in this tripartite model should be viewed as "a composite concept with three constituent elements."

2.3 LAND ADMINISTRATION AND CADASTRAL SYSTEM

2.3.1 Land administration

In order to understand the concept of land administration, we need to see its connection with land management. Land management is defined in a short statement as "the process by which the resources of land are put into good effect" (UNECE, 1996, p. 13). Land management encompasses all activities associated with the management and development of land and natural resources. It can embraces, for example, land tenure management, farming, the formation of land use and spatial planning policies and well as the physical development, property and estate management, natural resources extraction and management, land allocation, land readjustment and consolidation, urban landscaping, and land evaluation and environmental impact assessment.

Due to the country-specific context and regulations, the activities and organizational structures for land management differ widely between countries and regions (Enemark, 2005). Nevertheless, in general, within the context of sustainable development, land management paradigm usually relates to land administration. Land administration interacts closely and inseparable with land policies (by Williamson et al., (2010) defined as the set of aims and objectives as part of the national policies concerning land and its developments to promote economic development, social justice and equity, and political stability) and takes land information infrastructures (i.e., cadastral and topographic datasets) as a basis of administering land. Then, according to Enemark, land administration is considered as a process in implementing land management, or a series of activities of land management, or a tool of land management, which functions in the aspect of:

- land tenure, which is related to tenure governance and legal certainty for land rights, land boundaries, land purchase and lease transactions, and management and handling disputes regarding land rights and boundaries;
- land value, related to the valuation of land or property for taxation, compensation, national revenue concerning land registration fees, input for calculate land sharing in land readjustment activities as shown in Demetriou (2016) and Feryandi and Adhie (2007), and the management and handling of land valuations and tax disputes;
- land use, related to planning and control of the use of land and natural resources through the application of planning policies and regulations, and the management and handling of conflicts regarding land use and natural resources;
- land development, related to the implementation of utilities, infrastructure and construction planning through permit planning and renewal schemes.

In line with Enemark, UNECE (1996, p. 14) defines land administration as "the process of determining, recording, and disseminating on information on ownership, value, and use of land" when implementing land policy through land management instruments. UNECE then further defines that those land records (i.e., ownership, value, use) and their management and distribution can create security of tenure and support land market (UNECE, 2004). Due to the fact and practice that the core idea of land administration is about land tenure, in another definition, FAO (2002, p. 12) narrows land administration as "the way in which the rules of land tenure are applied and made operational." Nichols (1993) puts forth his perspective that shortly, land administration is a mechanism to support the land tenure system, although Barry (1999) has a different contention that land administration serves broader objectives (as also argued by Enemark and Williamson et al. that connect land administration to wider purposes with relations to sustainable development).

This research will take the understanding from UNECE (1996, 2004), Enemark (2005) for further elaboration. This research defines that the systems that facilitate the process in administering land in the aspect of tenure, value, and use are called land administration systems, which according to Checkland (1981) and Barry (1999), can be viewed as a conceptual, not physically identifiable, system. In this research, a system is defined as "a set of elements together with relationships between the elements and between their attributes related to each other and to their environment so as to form a whole that aims to reach certain goals" (Zevenbergen, 2002, p. 87).

2.3.2 Cadastral system

When discoursing about land administration, literature usually also describes cadastral systems and cadastres. The definitions of those two terms are mixed and overlap in the literature (Effenberg, 2001; Sari, 2010). Yet, one common perspective concerning both is that it is an integral part of land administration, which operates by providing spatial integrity and unique identification of land parcels (Williamson et al., 2010). In connection with the differentiation of land legislation, cadastral system varies among countries and regions in terms of aim, working area, mechanism, and the sub-systems (Rickersey et al., 2003). Ideally, a cadastral system comprises the properties that emerge from the interaction and combination of two or more of the sub-systems that are (Barry, 1999):

1. Adjudication, which is the formal and authoritative determination of rights in land to people (FAO, 2002). If followed by the titling process, adjudication becomes first-time registration.
2. Boundary definition.
3. Surveying, activities for acquiring land records, including an activity to acquire boundary measurement and marking.
4. Registration, which is defined as the legal execution and record of the transfer of rights and interests in the ownership bundle.
5. Dispute resolution, which denotes a process to resolve disputes; and
6. Information management, including data capture, information processing and analysis, information storage, information retrieval, and information dissemination.

While the description from Barry does not mention the term cadastre, Bogaerts and Zevenbergen (2001) explain that a cadastral system is of two parts, namely the land registration and the cadastre. The land registration is a public register that keeps the documentation effecting interests in land. Silva and Stubkjær (2002) describe cadastres as the systematic and official description of land parcels, including written attributes of each parcel and a large-scale map that provides information on parcel boundaries and land records. Therefore, these perspectives define cadastres as spatial records or repositories, which can take the form of a land information system or a cadastral map. These records identify individual land parcels, including land rights, land values, land uses, and other relevant properties. Effenberg (2001) points that the cadastre is part of cadastral spatial system (focuses on spatial aspect) and the land register part of land conveyance system/land registration system (focuses on non-spatial aspects, i.e., legal records). The land registration and cadastre are complementing each other, and they operate as an interactive system (Hessen, 2010). Land registration part answers the question as to *who and how* while the cadastre answers the question *where and how much*.

The term "cadastres" do not always mean the spatial repository or the repository system, or only deal with where and how much questions, especially when it is related to context-specific cadastres. Forestry cadastre in Turkey, by Atasoy et al. (2015, p. 2) have been defined as "demarcation of forests and their registration into the land registry in the name of 'state' as a public property". This definition shows a cadastre as a process that includes the element of surveying and land registration, which is in contrary with Zeverbergen (2002) and Henssen (1995) that say that land registration is not the same with cadastre. Osterberg (2001, p. 2) even argues that the cadastre is "a process of adjudication land rights, of distributing/allocating land rights, of solving disputes around land use rights, of determining appropriate land use, of controlling land use, of facilitating land markets and of controlling the development on land markets". In his definition, Osterberg put cadastres as a process, with wider tasks, not as a just a repository system, and the process also has the same sub-systems with the definition of cadastral system from Barry (1999). Furthermore, Hannigan et al. (2018, p. 2) even describe cadastres as land administration systems:

"A cadastre is a land administration system for relating people to land, and includes the following elements:

- *a spatial referencing system (geodetic survey);*
- *an unambiguous parcel description system (including cadastral mapping);*
- *a titling system, ensuring rights to carry out certain activities;*
- *a land classification system as a basis for valuation;*
- *a revenue raising system, including rates and land tax; and*
- *a system for marking and reinstating boundaries on the ground (cadastral survey)"*

Those above definitions affirm that cadastral systems, cadastres, and land administration systems, to some degree, can replace each other as they may have overlapped in definition and elements. However, the common understanding is that cadastral systems and land administration systems are interchangeable with cadastres when cadastres are defined as a process. The other common knowledge is that land administration systems usually cover broader aspects than cadastres or cadastral systems can. However, their main services are no different: can be legal aspects (the cadastres are known as juridical cadastres) that deal with land registration, surveying, and boundary definition, or fiscal aspects (fiscal cadastres) that support land valuation process for taxation purpose, or both aspects. This research may use those definitions interchangeably, but most of the time will use the term cadastral system for consistency. There will be additional information if the statement will point clearly to the cadastre as spatial records of land parcels. The information is also given if the statement refers to the specific and internationally known names, such as marine cadastre (Binns, 2005), real estate cadastre (Busko and Meusz, 2014), urban cadastre (Dos Santos, Carneiro, and Andrade, 2013), rural cadastre (Dahlberg, 1984), or forestry cadastre (Atasoy et al., 2015).

In Indonesia, following the concept from Article 19 Paragraph 2 of BAL, practically the cadastral system comprises three activities:

1. Cadastral survey, which consists of cadastral survey, mapping, and recordation of spatial land parcel data. Recordation here refers to adjudication activity (which not followed by titling) and land data inventory either in a land information system (computer-based inventory) or in a cadastral map. Rusmawar, Sumarto, and Hadwi (2012) and Feryandi et al. (2014) state that these activities produce cadastral dataset and take its embodiment in "cadastral map". In some sense, these activities relatively close to the term cadastres (from a view as a process) that deal with spatial arrangements of land records (survey, mapping, and inventory).
2. Registration, which includes recordation of juridical data and transfer of rights.
3. Land certificate issuance. The certificate which will be valid as reliable evidence.

The disputes sub-system is not conceptually part of the cadastral system, but together with other sub-systems as stated in BAL, including land use planning dan land valuation, they are under Indonesian land administration and management.

For this research, that takes aquatic lands as the locus of implementation of the cadastral system, we will make a scope of definition that

1. Aquatic land cadastral system is a land-based cadastral system implemented in aquatic lands or in shore settlements. It is a system within Indonesian land administration and management.
2. This research focuses on boundary and surveying sub-system of the cadastral system. Therefore, the aquatic land cadastral system centers on the utilization on its spatial sections, namely cadastral survey and mapping activities (i.e., cadastral survey system) to define the reliable boundary as one fundamental aspect to secure tenure.

2.3.3 Cadastral surveying

According to Tamtomo (2006), in Indonesia, one of the core services of cadastral system is about determining the boundary of tenure for land registration and other purposes such as taxation or dispute resolution. Tamtomo uses the term "zonation of tenure". In broad meaning, boundary determination comprises the activity of boundary definition (identification), delimitation, demarcation, and measurement. While delimitation refers to the principal agreement between the landholders and the neighbors involved in the parcels, demarcation refers to the process of establishing the agreed-upon boundary through ground physical marks. For doing the boundary determination in the measurement phase, cadastral systems deploy a cadastral survey system which is, following the concept from Hannigan et al., (2018), defined in simple sentences as a system for marking and reinstating boundaries on the ground. Marking takes the form of the creation of new property boundaries (fixing) in the land division process. Reinstating means the re-establishment of the unclear existing property boundary. Zhang and Tang (2016) consider cadastral survey system is a sub-system (of cadastral systems) to provide spatial-related information to support land operations. Cadastral survey system is interchangeable in literature with land surveying, cadastral survey, cadastral survey and mapping, or just cadastral surveying. The term “mapping” is not always mentioned due to the common understanding that the mapping process is embedded in the survey process, and both of them are indeed a set of activities.

Surveying itself is classically defined by Donnely (2014, p. 13) as “the science of the accurate determination of the relative positions of points above, on, or below the earth’s surface for the planning and efficient administration of the land, the sea and any structures thereon”. Cadastral surveying is also often considered a branch of surveying, which creates, restores, marks, and defines property lines on parcels of land to describe individual ownership. All those definitions above conclude that cadastral surveying is concerned with determining the legal and physical extent to which land is owned. The result of cadastral surveying is a cadastral map, a piece of graphical information about surveyed parcels of land within a specified area. The map connects with other records as a system.

In principle, there are two types of measurement in cadastral surveying to obtain parcel boundaries: direct and indirect measurement (Craig and Wahl, 2003). In the direct measurement, the boundary data is directly obtained on the ground (i.e., field/ground measurement) and the results can straight be achieved within a continuous procedure or by applying further geoprocessing process. The direct measurements consist of terrestrial and extraterrestrial approaches. Examples for the terrestrial are measurement using tape meters, distometers, or tachymetry, while for the extraterrestrial, it is the measurement by means of Global Navigation Satellite Systems/Global Positioning Systems (GNSS/GPS), as shown, for example, by Wekker, van der Molen, and Lemmen Wekker, van der Molen, and Lemmen (2003). In the indirect measurement, the boundary measurement is conducted cartometrically using geospatial software on a medium, for example, on very high-resolution satellite imageries as shown by Ali (2012) and Rao et al. (2014) or on aerial photos derived from photogrammetry technology. Unmanned Aerial Vehicles (UAVs) now emerge as new technology from photogrammetry disciplines and have much potential for cadastral surveying, although some intensive investigation concerning their performance in various types of land is necessary.

2.3.4 Fit-for-purpose land administration

As has been mentioned earlier in the Background section, the fit-for-purpose concept (FFP) was developed by FIG and the World Bank in 2014 with a goal of closing the security-of-tenure gap as a response to the challenges of the overall global sustainable development agenda. It is obvious that this agenda cannot be achieved without having good land governance in place, including the operational component of land administration systems(GLTN/UN-Habitat, 2016).

Concerning the tenure gap, on a global scale, countries that have covered by formal cadastral services (i.e., cadastral surveys and land registration) through effective land administration systems are just around 30 percent and those that do not are 70 percent (McLaren, 2015; GLTN/UN-Habitat, 2016). One remark on why the divide is big, as argued by GLTN/UN-Habitat, is because “the traditional, western-style land administration system is simply too costly, time-consuming, and capacity-demanding” (p. vi). It is not a problem for developed countries. However, for most developing countries that still face difficulties regarding basic needs fulfillment, affordability is a relevant issue.

In Indonesia, with the total number of land parcels around 97.2 million, the divide between registered lands and unregistered is 57% to 43% (Dzihrina et al., 2017). Several concerns hindering the progress of land registration include a limited public budget and a limited number of human resources, particularly cadastral surveyors. The proportion of one surveyor to unregistered parcels is 1: 22,750. The other situation is a high-cost land registration, as this process requires a costly field survey and mapping and long procedures consisting of at least seven rigid steps and multilayer approvals that must be followed.

Looking at these backgrounds (i.e., costly, labor demand, unsatisfied results as shown by a big tenure gap), this new concept has been developed into three interconnecting frameworks

(Enemark and McLaren, 2017) consisting of several key principles that arguably might tackle the problem of duration and cost and, at the same time, be reasonable in quality, as shown below in Table 5 (GLTN/UN-Habitat, 2016):

Table 5. Key principles of the FFP approach

FFP Approach		
Spatial framework	**Legal framework**	**Institutional framework**
▪ Visible (physical) boundaries rather than fixed boundaries ▪ Aerial/satellite imagery rather than field surveys ▪ Accuracy relates to the purpose rather than technical standards ▪ Demands for updating and opportunities for upgrading and ongoing improvement	▪ A flexible framework designed along administrative rather than judicial lines. ▪ A continuum of tenure rather than just individual ownership ▪ Flexible recordation rather than only one register ▪ Ensuring gender equity for land and property rights.	▪ Good land governance rather than bureaucratic barriers ▪ Integrated institutional framework rather than sectorial silos ▪ Flexible ICT approach rather than high-end technology solutions ▪ Transparent land information with easy and affordable

Source: (GLTN/UN-Habitat, 2016)

Among those key principles, focusing on spatial and legal frameworks, this research uses the relevant principles and translates them into operational frameworks in aquatic land tenure arrangement, aquatic land cadastral survey system, and aquatic land value modeling within the context of Indonesian land administration systems.

2.4 LAND VALUE ESTIMATION

Land valuation is a generic name. It is often also called land appraisal. In general, there are two types of land valuations, namely ecosystem services valuation (economic/socio-ecological/environmental value assessment) and land parcel valuation (Directorate of Land Valuation ATR/BPN, 2014). In Indonesian terminologies, those are called “penilaian kawasan” and “penilaian bidang tanah”, respectively. In this thesis, the term land valuation refers to the latter.

IAAO (2013) defines valuation as "the process of estimating the value - market, investment, insured, or properly defined values - of a specific parcel of real estate or items of personal property as of a given date" (p. 179). In a practical definition, Ismail and Buyong (1998) state that property valuation can be defined as “a process of estimating property values for a certain purpose, at a certain time based on the property's characteristics by taking into account all the factors that can affect property value” (p. 249). Therefore, land valuation in this thesis also called land value estimation.

For an implementation practice and mainly on residential areas, the term land valuation is often replaced by real estate valuation, real property valuation, or just property valuation. This is because land is categorized as real property (i.e., property that is immovable, as opposed to a term personal property/movable property). The property itself is defined as vacant land plus anything permanently (called as attachments or improvements) attached to it (IVSC, 2013; IAAO, 2013). In residential areas, in general, there are building components that also need to be involved in the valuation process. So in this case, the term property describes buildings and vacant land as a whole, and the concept of property valuation, in general, is land valuation plus building valuation (and if necessary, the assessment of other components attached to it – whether above or below – which are limited by certain boundaries). This thesis will use the terms interchangeably when following the literature, but later in the analysis chapter will clearly differentiate between land value and building value as land value in this thesis refers to the value of vacant land (land without other permanent improvements on it).

In general, the value itself comprises of two things namely market value and assessed value (Notham, 1975 as in Hidayanti and Harjanto, 2003). Market value is the value based on the market price of a property. Price is an amount paid by a seller to a buyer in a property transfer/transaction for the exchange of ownership/occupation (Ismail and Buyong, 1998). A property is considered having a value in the market when it meets the combination of these four criteria that are: useful and beneficial, lack in supply, an effective demand, and can be transacted (Harith and Hamid, 1993).

Market price here means that the agreed price is assumed to originate from the ideal conditions of the open land market, which are (Board of Valuers, Appraisers and Estate Agents, 1987 as in Harith and Hamid, 1993):

- In an open offer (no special bid from a special purchaser).
- Both seller and buyer are willing to deal.
- The sellers and buyers have sufficient knowledge, experience, and information about the property being transacted.
- The offer period is sufficient, taking into account the nature of the property and the state of the market.

Value, in simple words, is an estimate of what the price ought to be. Hence, the assessed value asserts the estimated value of the assessment from the surveyors or appraisers. This research will use market value as the basic data to get the assessed value. In the context of land administration, land valuation is more onto land parcel valuation, considering the basis of the cadastral system is land parcel. Land parcel valuation, because the results are mainly used for supporting land administration and cadastral purposes (fiscal cadastre, for example), sometimes also referred as cadastral valuation (Novikova et al., 2018), and the result of the valuation process is called cadastral value. Another meaning of cadastral valuation is a valuation carried out by cadastral offices, which involve cadastral datasets as affecting factors of the value. Cadastral datasets are data in the form of parcel properties obtained from cadastral surveying or in looser meaning, data that supports the implementation of cadastral system. Some of the countries that use this term are Spain, Latvia, and Russia. This thesis still use the generic name, land valuation or land parcel valuation, following the formal name written in the standard from Ministry of Agrarian and Spatial Planning/National Land Agency (Directorate of Land Valuation ATR/BPN, 2014)

3 TENURE ARRANGEMENT

3.1 INTRODUCTION

In Chapter 3, we present a response to Objective 1. This chapter first delivers some supporting arguments and a national policy that contextualize the necessity of administering land in the coastal area of Riau Islands. After that, the chapter brings some concepts to frame the works of developing tenure arrangement. The analysis of the proper tenure arrangement is presented in two aspects: the optimum tenure forms and tenure form conformity. The analysis reveals the findings regarding what and where such tenure forms can be established.

3.1.1 Arguments that support tenure arrangement in shore settlements

Arguably, besides being motivated by the problem of tenure insecurity and its following implications, and the sounding fact that there are abundant shore settlements in Riau Islands to be administered properly, there are still other factual arguments (already slightly mentioned in the Background part) that support the importance of land tenure arrangement in the area.

Historical arguments

Facts reveal that some of the coastal settlements in Riau Islands where this thesis takes as study areas, have long existed even before the establishment of the modern Indonesian state. In the 15th-16th century, Riau Islands region was under the control of a maritime Malaka Sultanate following the decline of Sriwijaya Empire in mainland Sumatera. After that, the area was governed by maritime sultanate triangle: Johor-Riau-Lingga until the early 20th century at the time Dutch colonial took power completely (Koestoro, 2015). During that royal era, many coastline cities were developed, such as Daik in Lingga Regency, Tarempa in Anambas, Natuna in Bunguran Island, Tanjung Uma in Batam, and Tanjungpinang. In Tanjungpinang, Melayu Kaca Piring, a small coastal village was opened by an admiral from Johor for fisheries activities, trade, and expansion mission. Its strategic location that connects Johor in the northwest and Lingga Sultanate in the southeast, made that small coastal village to develop fast and became a center of activities and the capital of Johor-Riau-Lingga Sultanate since early 17th century. At about the same time, Senggarang, a coastal area in the northern side of Melayu Kaca Piring was opened also for a shipping port run by Chinese traders. Later, the royal residence were established in Penyengat Island for Yang Dipertuan Muda Riau-Lingga (Riau Lingga Crown Prince), that made the coastal settlements grew larger.

Besides Melayu Kaca Piring, Sengarang, and Penyengat as the city centers, small supporting villages like Teluk Keriting, Kawal Pantai, Kijang, Mapur, and Mantang in Bintan, Belakang Padang Island in Batam, Lipan in Lingga were also developing. In those areas, Suku Laut [the Sea People], known as the sea wanderers of old Malay ethnic group, usually stayed temporarily for three or four months during strong wind season, for taking care of their small cultivation in the islands, before wandering again by their boat-houses across the sea and along the coasts for collecting fish and doing trade (Dahlan, 2014). Nowadays, those coastline areas are still inhabited and some even become the center of activities in the region.

From that short flashback, it should be noted that the long existence of all those settlements denotes that the de facto tenure between the local people and their land is historical, already existed for centuries, and was not just created by recent occupation (except in urbanized areas, in Batam or Tanjungpinang Kota Sub-district, for example). From the other view, the preference to first open the settlement and occupy lands in coastline areas (not in the inland areas) even in the big islands such as Bintan, Batam, Galang, Karimun Besar, Bunguran, Lingga, and Singkep, where the empty land was still available at the time, reveals their identity as coastal communities that has chosen the unique way of living (dependent to both: marine and land). Coastal communities are defined as groups of people living in coastal areas, using the amenities given by land, but most of the sources of their economic life depend on the use of marine and coastal resources either in fisheries such as fishing workers, fish breeders, fish traders, fish production workers or in non-fishery activities such as sea transportation workers (Nikijuluw, 2001).

In traditional communities, as still seen in some of the study areas in Dendun Island, Kelam Pagi, and Penyengat Island, the locals even invented local norms and knowledge. They arrange how lands in aquatic areas should be allocated for housing and for other usage as “karamba” the small pond for fish breeding; “bagan” the small house-like structure for capturing fish and initially processing it on-site; and the “gonggong”, a coastal water mollusc (Strombus Canurium) harvesting area, which is really valuable in the culinary market.

Therefore, considering those above facts, as also emphasized by Tamtomo (2006) and Budiharsono (2005), the neglect of the tenure setting in coastal areas is ahistorical, disrespectful to the local traditions and customs, and a kind of repudiation of the character as an archipelagic region. Therefore, Tamtomo argues that recognition of the coastal property rights, either for communal rights of indigenous/traditional communities or for the entitlement rights by the individuals in coastline settlement areas, should be fully arranged by the authority.

Administrative arguments

No different from other Indonesian citizens, the residents in the settlements get a Kartu Identitas Penduduk/Resident Identification Card (KTP) from Dinas Kependudukan dan Catatan Sipil/Office of Civil Registration and Population Affairs of the city authority. The card indicates not only a validation of the citizenship but also an affirmation about their residential address where they domicile. In the urban settlement, such as in Tanjungpinang Kota and Kamboja, the identification is even more complete with a house number and street address besides the name of the formal administrative tiers: “Rukun Tetangga (RT)”/Neighbourhood Association, Rukun Warga (RW)/Resident Association, village, subdistrict, and regency. The assignation of street names in the coastline settlements and the establishment of formal administrative structures show that from the juridical view, the area meets the aspect of legality and legitimacy (Whittal, 2014) under the existing governance system and does not appear as slum areas or illegal/informal settlements. From the taxation side, the residents who live in coastline houses must pay the land tax, which consists of tax for the land and tax for the building. The tax is collected every year by Dinas Pendapatan dan Pengelolaan Keuangan dan Aset Daerah (Office for Management of Regional Revenue, Finance, and Assets).

According to Van Gelder (2010b), when the government gives out KTPs and collects taxes, this is called "de facto tenure recognition." This means that the government recognizes that the person whose name is on the card is the legal resident and, as a result, has the right to stay and live at the given address, but they are also required to pay taxes on their land. As said by Sofyan (2016), this legitimate administration (from the side of the subjects/the residents as well as from the side of the clearance area) should provide a first-stage compelling administrative basis to arrange the tenure in formal circumstances.

Physical development in the settlements

Another type of de facto tenure recognition is when there is infrastructure development in the settlement facilitated by the authorities (Van Gelder, 2010b). In Riau Islands Province, the local government built jetties for boat landings, provided permanent roads, and installed public utilities like electricity, sanitation, and clean water. It even established fixed telephone lines, as seen in Tanjungpinang Kota and Kamboja Villages. The government also implemented a program called RS-RTLH (*Rehabilitasi Sosial Rumah Tidak Layak Huni*/Social Rehabilitation for Not-livable Houses) through Dinas Pekerjaan Umum dan Tata Ruang (Office of Public Works and Spatial Planning). The program aims to build and renovate houses. In Kampung Panglong Berakit in the northeast part of Bintan Regency, for example, there are more than 30 houses had been renovated (Jayusman et al., 2018). This provision of physical infrastructure instead of relocating the people living in the coastline area should be seen not only as the fulfillment of the Government Regulation No. 44 of

2016 on Housing and Settlement Management that gives the government obligation to increase the facilities for the settlements nationwide, but also as the consideration and again, the circumstantial support of the recognition of the local way of inhabiting lands in the coastlines areas.

3.1.2 National policy and international agendas

In addition to the factual arguments above, Agrarian Reform could become the policy basis for implementing land tenure administration in the areas along the coastline. Agrarian Reform has been initiated since 2011 by the People's Consultative Assembly Decree IX of Agrarian Reform and Natural Resource Management (TAP MPR No. IX/2001) and is currently one of the focuses of development programs as stated in Presidential Regulation No. 45/2016 concerning The Government Action Plan 2017. Presidential Regulation No. 86 of 2018 concerning Agrarian Reform, stating that Agrarian Reform is an agenda to restructure the tenure, ownership, use, and utilization of land assets. The regulation considers land as assets, a manifestation of the concept of land as the property that has the potential to be developed to improve living standards and prosperity.

Kantor Staf Presiden/Presidential Staff Office (KSP) describes six interconnected strategic programs inside the reform (KSP, 2018) that are

1. Strengthening the regulatory framework and resolving agrarian conflicts.
2. Arrangement of land tenure and ownership.
3. Legal certainty of land.
4. Community empowerment in land use, land utilization, and agricultural production.
5. Allocation of forest resources to be managed by the people.
6. Restructuring implementing institutions in the central and regional level.

Together with the regulatory and institutional arrangement, Agrarian Reform is practically implemented through asset arrangement and access arrangement. Assets arrangement consists of land redistribution and land legalization. Access arrangement is the provision of opportunities and facilities to access the loan from financial institutions, and the provision of other necessary assistance to utilize land optimally, which is also called community empowerment (Presidential Regulation No. 86/2018 Article 1 point 3). Looking at the broad scope of agrarian reform, it can be said that this reform is a unifying platform for implementing several activities related to the land administration system.

The Agrarian Reform is a response to the significant imbalances in land ownership. Konsorsium Pembaruan Agraria (KPA) published that only 6% of the total land is occupied by individuals; the rest is occupied for mining, forestry, and plantation sectors (KPA, 2017). Besides that, Koalisi Kerakyatan untuk Keadilan Perikanan/People Coalition for Fisheries Justice (Kiara) adds that the reform has been programmed to reach groups of people whose tenure is still not fully recognized by the state and hence be in a conflict-prone situation, such as in coastal areas and small islands (Kiara, 2017).

Agrarian Reform is mostly focused on forestry and other state-controlled lands (like ex-mining land and expired-righted land), especially along the coast and on small islands. However, Presidential Regulation No. 86/2018 says that Agrarian Reform can also happen in the area known as *tanah timbul* or *tanah tumbuh*. The Circular Letter of the Minister of Agrarian/National Land Agency No. 410-1923/1996 on Tanah Timbul and Reclamation Land explains that *tanah timbul* is land that arises naturally, commonly found in deltas, coastlines, lakesides, riverbank deposition, and arising islands. *Tanah timbul* may be temporarily inundated (during high tide) or already fully in the form of land (no longer inundated). As already known, in coastal regions, *tanah timbul* is a common location for coastline settlements, at which the tenure arrangement is very relevant to be implemented as an effort to avoid tenure confusion.

The other policy basis of implementing land tenure arrangement for securing tenure is the Sustainable Development Goals (SDGs). In Goal 1, End Poverty, especially in Indicator 1.4.2, "Proportion of total adult population with secure tenure rights to land, (a) with legally recognized documentation, and (b) who perceive their rights to land as secure, by sex and type of tenure", it is stated clearly the goal that aims to provide secure tenure rights to all men and women, including indigenous peoples and local communities. In SDG 10: Reduced Inequality, it is stated that by addressing land inequality and ensuring equitable access to land, secure tenure can help reduce social and economic disparities.

The Voluntary Guidelines of Responsible Governance of Tenure of Land, Fisheries, and Forests in the Context of National Food Security (VGGT) by the Food and Agricultural Organization (FAO) are another international framework that works to make tenure security important. The VGGT outlines core principles, such as respect for human rights, gender equality, and the rights of indigenous peoples and local communities. The framework also emphasizes the importance of transparency and accountability in land governance, including public participation and access to information. It concludes strongly that secure tenure rights are essential for achieving food security. When people have secure tenure, regardless of where they reside, they can optimally utilize their land by investing in it and improving productivity. The VGGT also promotes equitable access to land, fisheries, and forests in responsible land governance (FAO, 2022).

3.1.3 Frameworks in arranging tenure in shore settlements

As mentioned previously in Table 5, one of the main principles of the fit-for-purpose land administration approach is the continuum of land tenure. This principle reflects the "inclusive" element in the fit-for-purpose approach where according to FIG and Worldbank (2014) inclusive means "in scope to cover all tenure and all land" (p. 8). In this research, the continuum of land tenure concept provides a perspective on how we should take a look at the tenure as an evolving construct. Argumentations from Tamtomo (2006) and Puslitbang BPN (2010) when conducting a study related to land management in coastal areas of Indonesia, it is also taken for framing which formal rights (statutory) are appropriate. In studying tenure conformity, this study discusses it based on juridical-spatial-based tenure allocation principles as brought by Puslitbang BPN (2010); Sofyan (2016).

3.1.3.1 Continuum of land tenure

Continuum of land tenure is a concept that states even though land tenure is often understood in a binary term, in practice tenure can actually take a variety of forms in a continuous sequence, in the sense that tenure forms sit on a continuum between informal and formal rights In between these two extremes is situated a wide and complex range of rights embedded with its advantages and disadvantages with regard to tenure security.

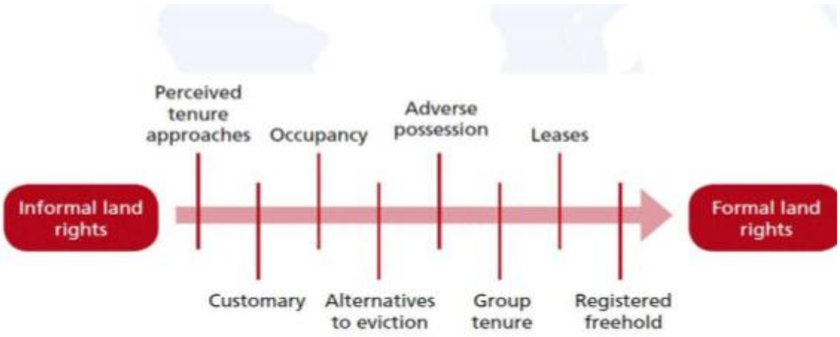


Figure 7. The continuum of land rights (UN-Habitat, 2008, p. 8)

On the right side of the Figure 7 are formal land rights that are recognized by law, and on the opposite pole are informal rights that are not administered by the state and may not be recognized by it. A lot of different types of tenure can be found in the middle, such as customary tenure, religious tenure, occupancy, tenure based on adverse possession (continuous possession that is illegal at first but then becomes legal), leasing systems, and group tenure. They may evolve, overlap, and transform when any change occurs, and they are likely to be supported by a mix of formal (state systems) and informal (non-state) institutions.

The continuum is widely recognized as a key part of evolving global land tenure understanding, providing the following practical insights (Plessis et al., 2016).

1. Recognizing, recording, and administering various appropriate and legitimate land tenure forms is the direction towards sound land administration.
2. The number of tenure forms that are appropriate, robust, effective, and legitimate depends on history, culture, policy, and regulations.
3. The concept delivers an alternative approach to the dominant focus of titling of individually held private property as the ultimate form of tenure security or as the end goal of land tenure reforms.
4. It promotes the increase of security across the continuum, with the opportunity for movement between tenure forms, including tenure form upgrading, from just an oral-based to the letter-based.

With multiple stakeholders and interests attached to land possession in coastal areas, the concept of a continuum of tenure that provides flexibility is arguably more applicable. Tenure pluralism is adapted in the sense that instead of limiting the form of tenure that would be applied to coastline settlements and focusing just on one or two forms, it is more pertinent to take "all relevant non-statutory forms that exist and evolve in society and the ones that are provided by statutory instruments", from both land-based and marine-based forms, both oral and written, and then implement them accordingly.

The identification of diverse tenure forms, followed by the selection of contextually appropriate options, offers alternatives to registered formal tenure. Given that formal registration is often complex, this approach is particularly relevant in aquatic environments. It is posited that land tenure arrangements in aquatic areas will differ from those in Indonesia's hinterland regions. In this framework, formal tenure should be considered as one among a spectrum of viable tenure options, rather than the exclusive or primary source of tenure security.

3.1.3.2 Differentiation between sea and coastal waters

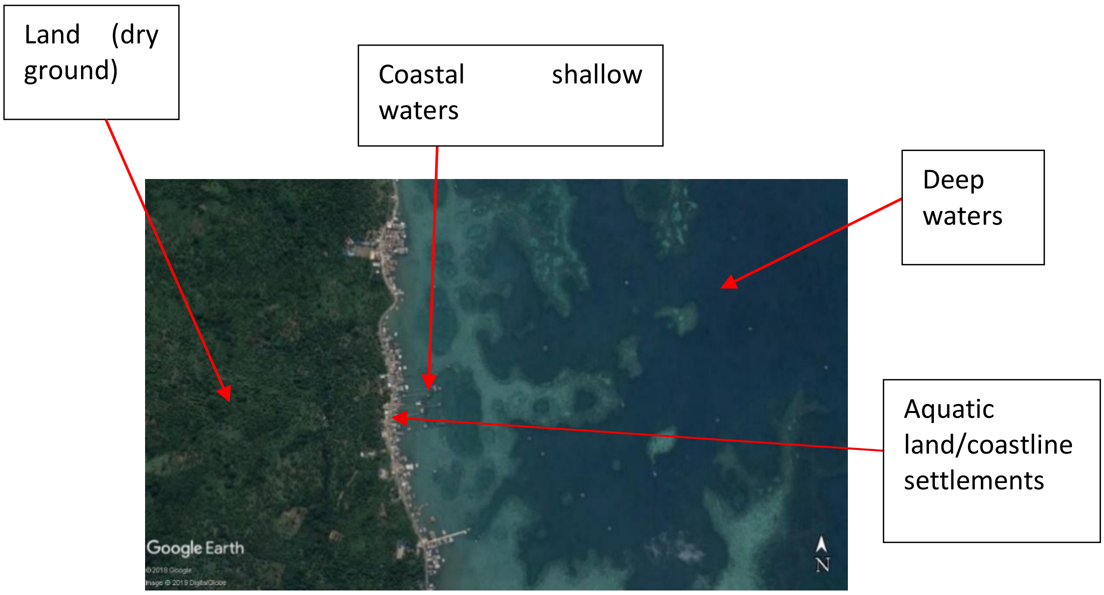
Common perspectives had been placed all marine areas under the "mare liberum" and "rus nullius" concepts. The sea environment is free for all and owned by no one. However, in more thoughtful consideration, the perspective can be different for archipelago countries that have territorial seas and coastal waters within their sovereignty (Tamtomo, 2006; Purwaka, 2014). Initially after 1945 independence, in managing its marine environment, the Republic of Indonesia still referred to the

1939 Dutch Indies Ordinance, Teritoriale Zeeën en Maritieme Kringen Ordonantie 1939 (Tamtomo, 2006).

Under this rule, the sea separates islands within the archipelago. The country authority can govern and manage marine areas within the normal baseline of 3 nautical miles from the coastline. The sea after the 3 nautical miles is the international free sea. Foreign ships are free to navigate the sea separating the islands, and other countries have the right to manage resources beyond 3 miles (ca. 5 km) from the coastline.

In 1957, Indonesia declared the Djuanda Declaration which pronounced the concept of “wawasan nusantara”, where Indonesia as a sovereign country is predicated on clear territorial boundaries that encompass both land (*tanah*) and water (*air*). The declaration implied that the colonial regulation did not fit with the geography as an archipelagic country and clearly proclaimed that Indonesia had deserved to obtain its own territorial sea (inter-island sea) calculated from the archipelagic baselines that join the outermost points of the outermost islands and not from the normal baseline calculated from the coastline (Sodik, 2018). The area is the area of sovereignty, both in the concept of state administration and resources management (which implicitly includes the land tenure arrangement concept) and foreign parties have no free rights to access and extract the resources. This concept then rolled internationally and received further legitimacy after a global acknowledgment emerged in 1982 with the establishment of the United Nations Convention on the Law of the Sea 1982 (UNCLOS 1982). The Indonesian government then ratified UNCLOS 1982 by enacting Law No. 17 of 1985 concerning Ratification of UNCLOS 1982. According to UNCLOS 1982, a coastal country and an archipelagic nation have the sovereignty rights to a sea area as wide as 12 nautical miles from the baseline (Purwaka, 2014).

Then, Law No. 27/2007 followed it up by stipulating a delegation of management rights for provincial and municipal government in the area of 12 miles (ca. 19 km) and 4 nautical miles from the coastline. In 2014, Law No. 23/2014 concerning Regional Government, the authority of municipal government was eliminated, and the management of coastal areas was fully controlled by the provincial government. Global acceptance of UNCLOS 1982 led to a paradigm shift. The ocean resources were agreed to be the "res communes" or “shared property, but at the same time, sovereign countries characterized by archipelagos have rights to manage their marine area in the inland waters, archipelago waters, and territorial sea as a reflection of marine and coastal administration in accordance with the character of each country (Binns, 2005). Some countries, such as Canada, the US, and Australia, adopted this "property concept" and the necessity of a marine governance system as a marine cadastre concept. Despite conducting several studies, Indonesia's current land administration system has not adopted the marine cadastre concept as seen in Tamtomo (2006), Astor et al. (2014), Djunarsjah (2008).



Location: Matak Island, Anambas Regency

Figure 8. Illustration of differentiation between shallow coastal water and deep sea water

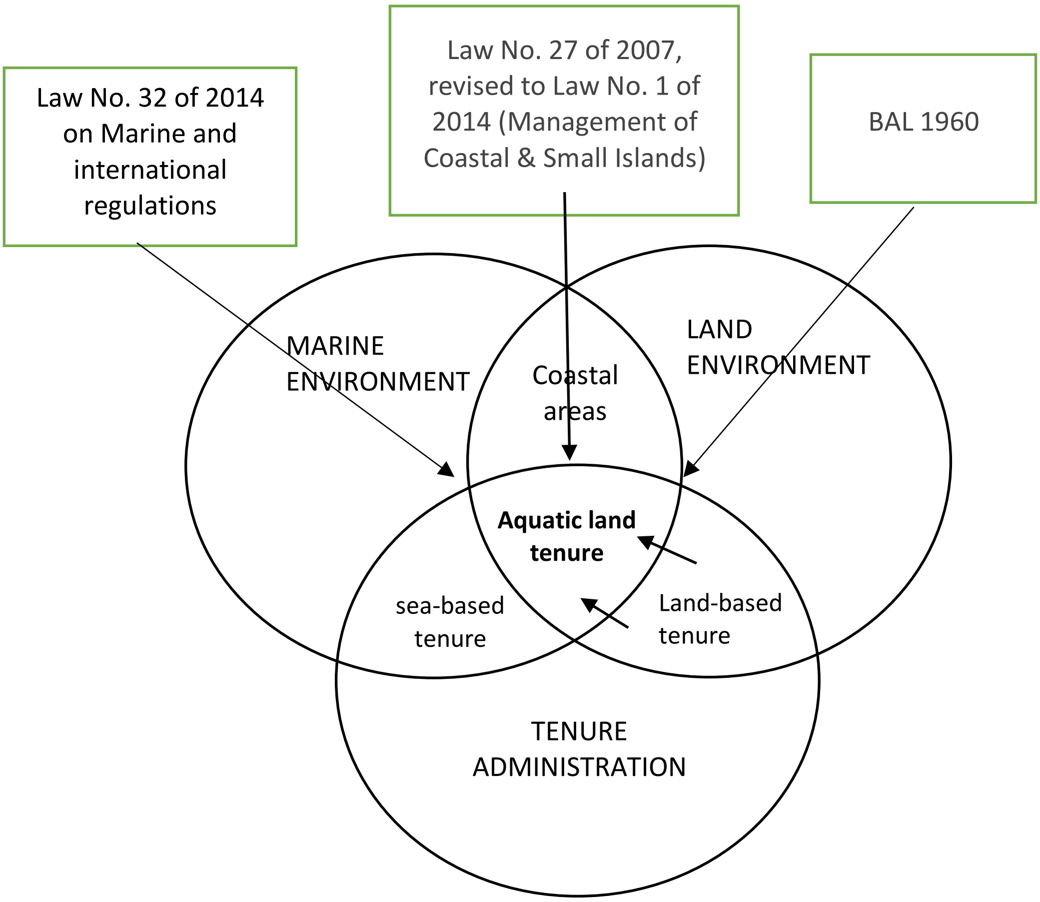


Figure 9. Tenure for aquatic lands following the argument from Tamtomo (2006)

In the context of the Indonesian land administration system, it is important to examine in more detail the concept of tenure arrangements in coastal waters (or aquatic lands) and sea waters (Tamtomo, 2006; Adrianto, 2012). Physically, coastal waters are different from the sea waters, even though both are inseparable entities. Coastal waters are shallow waters, containing the intertidal area where at low tide it appears as land. Coastal waters are also the continuation of the activities on land; hence, the land use and utilization pattern still contains strong influences from land, especially in the coastline settlement areas. In contrast, in seawater space, which is farther from the coastlines and fully submerged, the influences from the land side can be said to be small or tend to be non-existent. The ecosystem in this deep water space is also normally different from the one in shallow waters.

To this regard, Tamtomo (2006) argues that in order to develop tenure arrangement in aquatic lands, the types of formal rights that can be held by individuals and legal entities should respect this separation (see Figure 9). Therefore, in coastal waters, the proper rights include the rights not only from the marine-based regime specifically for coastal areas under Law No. 27 of 2007, which was revised with Law No. 1 of 2014 on Coastal and Small Islands Management, but also from the land-based regime under BAL.

The reason why the rights for land stipulated by BAL can be relevant is because BAL itself considers the area covered by water is still categorized as land (Article 1). Besides that, in the settlement areas where building-based usage and individual small-scale possession dominate, only the land-based regime from BAL has so far provided the potential rights. The potential rights for non-built-up areas surrounding the settlements stem from coastal and small island regulations. To deep sea waters, the tenure is form pure marine-based regime, which is under Law No. 23 of 2014 on Marine and other international regulations (e.g., UNCLOS 1982 and International Hydrographic Organization/IHO regulations). However, the deep-sea waters are out of scope in this study.

3.1.4 Research activities

Tenure arrangement study in this thesis generally is divided into two stages of analysis: a multicriteria analysis to obtain optimum tenure forms as a main analysis and a follow-up descriptive tenure conformity analysis to gain conformed/positioned tenure forms.

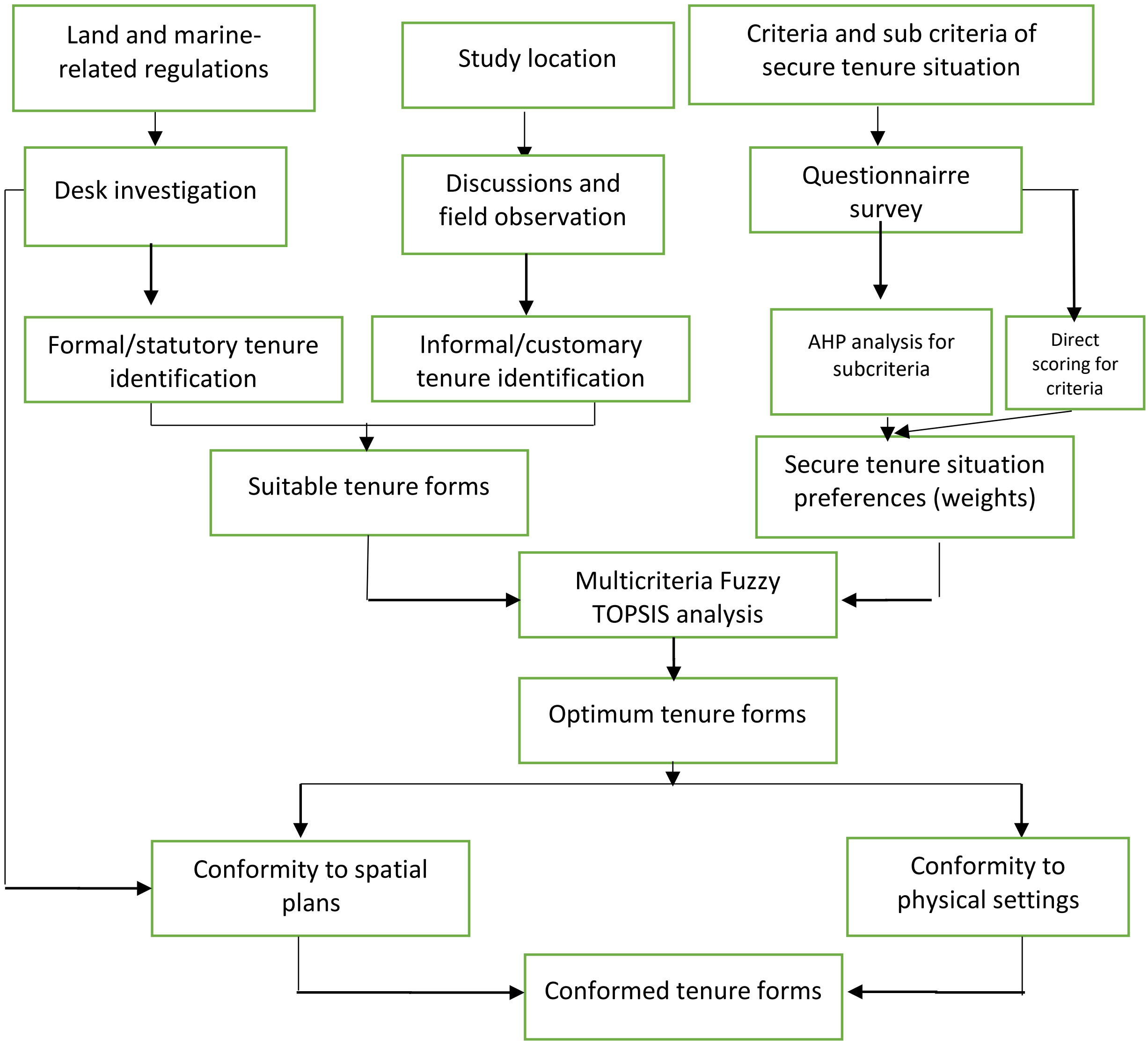


Figure 10. Research activities for tenure arrangement analysis

The flowchart (Figure 10) can be described as below:

1. Using a simplified statute approach (based on legislation and regulations) and conceptual approach (based on literature and other readings), following Putri and Sesung (2018), Soekanto (2006), the desk study investigates tenure administration regulations (from land-based regulations and marine-based regulations) to obtain potential statutory tenure forms. Parallel with it, the study location is observed to acquire information about non-statutory tenure forms. Both investigations produce suitable tenure forms.
2. Based on the secure tenure concepts, we parameterized criteria and subcriteria about secure situations. The subcriteria are more detailed manifestations of the criteria. By the respondents, the criteria were rated (1–6 scale), whereas the subcriteria were compared to each other (inside the same criteria) using a pairwise comparison of the AHP format. After running the questionnaire survey in the selected study areas, the obtained data was then analyzed using

AHP techniques to get the weight of every subcriteria. The weight of each subcriteria determines the ranking, indicating the more and less desirable secure situation.

3. The next step was a tradeoff analysis between suitable tenure forms and the desired secure situations by deploying multi-criteria Fuzzy TOPSIS analysis. In this analyzis, the weights from AHP as the quantitative input was used. Fuzzy TOPSIS then delivered the optimum tenure forms as the result, arranged in a sequence. Here, "optimum" refers to a balance between the secure situations people desire and those that suitable tenure forms can facilitate.
4. Following that, each valid tenure form was carefully examined to make sure it fits within the designated areas. The term "fit" means that both the legal forms that are assigned to a piece of land and the non-legal forms that are present on that land do not violate the rules set by any given zone. The conformity of every tenure form was also determined based on the characteristics of the area where the parcel is located. The investigation delivered conformed tenure forms, in the sense that those tenure forms are spatially in the parcels that are located in the right zone and area.

3.2 Data and Information

Data and information used as analytical material to obtain a proper tenure arrangement for aquatic land settlement in this thesis are:

3.2.1 Regulations

This study uses some published and operating regulations from the authorities (see Table 6) to collect information regarding tenure forms and tenure arrangements for Indonesian coastal areas.

Table 6. Regulations related to coastal tenure arrangement and land management

No	Regulations	Concerning on
	Land-based regulations	
1	Basic Agrarian Law (BAL/Act No. 5 of 1960)	Basic Regulations concerning the Principles of Agrarian Affairs
2	Minister of ATR/Head of BPN Regulation No. 10 of 2019	Procedures for the Establishment of Communal Rights on Indigenous People's Land and Communities Under Specific Areas
3	Minister of ATR/Head of BPN Regulation No. 14 of 2024	Implementation of Land Administration and Land Registration of Customary Law Community Ulayat Rights.
4	Law No. 4 of 1992 (UU No. 4/1992)	Housings and Settlements
5	Government Regulation No. 44 of 1994 on	Householding by Non-Owners (replaced by Government Regulation No. 14 of 2016 on Provision of Housing and Residential Area)
6	Law No. 26 of 2007 (UU No. 27/2007)	Spatial Planning
7	Tanjungpinang City Regulation No. 10 of 2014	Regional Spatial Planning 2014-2034 (revised by Regulation No. 11 of 2024 concerning Regional Spatial Planning of 2024-2044)
8	Presidential Regulation No. 32 of 1990	Management of Protected Areas
9	Government Regulation No. 24 of 2007	Land registration
10	Government Regulation No. 40 of 1996, replaced by Government Regulation No. 18 of 2021	Right of Management, Land Rights, Apartment Units (Strata Titles), and Land Registration

Table 6 (continued)

11	Government Regulation No. 16 of 2004	Land Use Management
12	Government Regulation No. 18 of 2021 (PP 18/2021)	Management Rights, Land Rights, Flat Units, and Land Registration
13	Minister of ATR/Head of BPN Regulation No. 17 of 2016	Land Management in Coastal Areas and Small Islands
14	Minister of ATR/Head of BPN No. 18 of 2021 (Permen ATR/Head of BPN No. 18/2021)	Procedures for Determining Management Rights and Land Rights
	Coastal marine-based regulations	
1	Law No. 27 of 2007 (UU No. 27/2007), followed by Law No. 1 of 2014 (UU No. 1/2014) on the Amendment of Law No. 27 of 2007	Management of Coastal Areas and Small Islands
2	Riau Islands Province Regulation No. 6 of 2006	Fisheries Activities in Riau Islands Province
3	Minister of Fisheries and Marine Affairs Regulation No. 16 of 2008	Planning on Coastal Areas and Small Islands
4	Minister of Fisheries and Marine Affairs Regulation No. 23 of 2016	Management of Coastal Areas and Small Islands
5	Government Regulation No. 60 of 2007	Conservation of Fishery Resources
6	Minister of Fisheries and Marine Affairs Regulation No.17 of 2008	Conservation Zones in Coastal Areas and Small Islands
7	Minister of Marine Affairs and Fisheries Regulation No. 54/PERMEN-KP/2020, continued by Minister of Marine Affairs and Fisheries Regulation No. 28 of 2021 on Marine Spatial Planning Management (Permen KP No. 28 of 2021)	Location Permits, Management Permits, and Offshore Location Permits
8	Minister of Marine and Fisheries Regulation No. 28 of 2021 (Permen KP No. 28/2021)	Marine Spatial Planning Management

3.2.2 Field observation and discussions with the locals

The observation was made to find out about the non-statutory tenure forms that exist in coastal areas. This includes information about how land is transferred, the occupants' obligations, and any other information about the length, breadth, and assurance of tenure. The observation was done in all 13 study areas (Table 4), and the informal interview with the locals was made in seven meeting points (Tanjung Unggat, Pelantar Pasar/Pelantar Kamboja, Kelam Pagi-Dompak, Madong, Tanjung Sebaok, Penyengat Island, and Dendun Island).

3.2.3 Preferred secure situation

From the concept of land tenure security outlined in Chapter 2, we notice that essentially the concept provides some secure conditions or indicators, which by Hanstad (1999) was categorized into breadth, duration, and assurance. Breadth is related to the quality of land rights held, which includes, for example, to pass, to transfer (sale or lease) to other parties, to pledge rights as security for credits, to prevent trespass, to build structures and extract resources. Duration as de facto security can be simply defined as the length of occupation (Van Gelder, 2010a). Assurance is a measurement of breadth and duration, as the effect of enforcement of the rights, which was explored by Nguyen (2012), may be reflected in recognition (as the result of land recordation and registration) and minimum disputes (as the result of dispute resolution action). For the use of this thesis, those three interconnected situations were developed and parameterized into six proposed criteria of secure tenure situation:

1. Convenience in using land. This study defines convenience in using land as a convenience and an easiness to optimize land for certain use and interests as needed by the holders, with no obstacles from the regulations.
2. Convenience in transferring land. In Indonesian land law, land transfers are called "peralihan hak." This term is defined as the convenience and easiness to transfer land to another party using inheritance and transaction modes of transfer. The transaction is defined loosely and incorporates any peralihan hak activities as written in buying and selling, or any process of doing business in the property sector (leasing, auctions, grants, or participation as a company capital).
3. Duration. Duration measures the length of time for which the rights to land are valid.
4. Accessibility and opportunity. Defined as the opportunity and facilities that can be accessed and achieved.
5. Recognition. This study outlines recognition as an evident state when someone's landholding is recognized by the other parties, such as the government authorities or the neighbors.
6. Security, which denotes a perceived condition of no menace for landholding.

Every criteria then was itemized into subcriteria to demonstrate the options (alternatives) of secure situations (see Table 7```). Majumder (2015, p. 36) suggests that the alternatives of multiple-criteria decision analysis should be “available, comparable, real, not ideal, and practical/feasible“. So, the development of the subcriteria uses some information from field observations, such as the kind of land use and land utilization practices in the coastline settlements (e.g., for multiple usage, for commercials, or just for housing) and the type of opportunities the landholders may gain if their tenure is respected and recognized (e.g., loan from financial institutions, better transactions and compensation, infrastructure supports). In developing the alternatives, the criteria reflecting de jure, de facto and perceived security view was also installed. For example in recognition criteria, there are alternatives of de jure security (based on formal land documents from the authority/Land Office) and de facto security (based on the neighborhood acceptance and recognition, and the supporting administration from the government). Another subcriteria that denotes de facto tenure situation is the availability of the opportunity to obtain physical infrastructure support from external parties.

We also incorporated criteria reflecting de jure, de facto, and perceived security views in the development of the alternatives. For instance, when it comes to recognition criteria, there are two options: de jure security, which is based on official land documents from the authority or Land Office, and de facto security, which is based on acceptance and recognition from the neighborhood and help from the government. The possibility of getting help with physical infrastructure from outside sources is another factor that points to a de facto tenure situation.

Table 7. Criteria and subcriteria of secure situation

Prefered situation (criteria)		Option (subcriteria)	
A	Convenience in using land	A1	Convenience to use land for various type of usage
		A2	Convenience to use land for housing
		A3	Convenience to use land for aquaculture activities
		A4	Convenience to use land for commercials buildings
B	Convenience in transferring land	B1	Convenience of inheritance
		B2	Convenience in transactions with Indonesian
		B3	Convenience in transactions with foreigners
C	Duration	C1	Unlimited time of occupation
		C2	Long period of occupation and usage (>10 to until the maximum period allowed by the regulations)
		C3	Short period of occupation and usage (max 10 years)
D	Accessibility and opportunity	D1	Higher possibility to access credit from bank/financial institutions
		D2	Higher prices in transactions and compensation
		D3	Easier access to get developmental supports/aid (e.g., electricity, clean water, road infrastructure, public buildings, fishing facilities, etc) from the government/other institutions
E	Recognition	E1	Administrative recognition in a residence card or other administration documents
		E2	Recognition in the legal documents of the land (e.g., certificates, permits, deeds, contracts) by the tenure authoritative bodies
		E3	Recognition by neighborhoods
F	Security	F1	No fear of/minimum/no evictions and land expropriation
		F2	No fear of/minimum/no potential disputes

Source: Author

Data about the preferred secure tenure situation was acquired from the questionnaire survey. The questionnaire consists of a combination of ranking evaluation for each criteria and the Analytical Hierarchy Process (AHP) pairwise comparison of the subcriteria of the preferred tenure security within the respected criteria. Face-to-face questionnaire interviews were conducted at all studied settlements. The quota for non-probabilistic samples per settlement is 10% of the number of household in each settlement. The number of the household was estimated by means of high-resolution satellite imagery. One building was assumed as being one household. Source data (interview partners) have been the heads of the villages and their secretaries, heads of neighborhood association (RT), heads of resident association (RW), informal leaders, and the old residents who have settled long to obtain the information from the residents who really have lived in the area. In total there were 399 respondents. Appendix 2 shows the questionnaire.

3.3 Analysis and Results

3.3.1 Identification of potential tenure forms

3.3.1.1 Statutory tenure forms

Statutory tenure is the tenure put in place by the government within the formal system based on written legal regulations. In Indonesia, according to Law No. 12 of 2011 about the Establishment of Legislation Law, the hierarchy of legislation is ordered as follows:

1. The constitution of the Republic of Indonesia 1945 (UUD 1945)
2. People's Consultative Assembly Decree (Tap MPR)
3. Law/Government Regulation in lieu of Law (UU/PERPU)
4. Government Regulation (PP)
5. Presidential Regulation (Perpres)
6. Provincial Regulation (Perda Provinsi)
7. City or Municipality Regulation (Perda Kab/Kota)

Lower-level regulations must be based on and must not be contradictory to higher regulations and must seek validity from higher legal norms to create a so-called "chain of validity" (Asshiddiqqie and Safa'at, 2006). As an example, in the scope on Spatial Planning regulation in Indonesia, the Municipality Spatial Plans (*RTRW Kab/Kota*) must follow the Provincial Spatial Plans (*RTRW Provinsi*) and the National Spatial Plans (*RTRW Nasional*). There are also regulations established by sectoral governmental ministries/agencies, such as Minister Regulations (Permen), Minister Decree (Kepmen), Head of Agency Circular Letter (Surat Edaran Kepala), Minister Circular Letter (Surat Edaran Menteri), and Standards and Guidelines (SOP or TCK).

Those sectoral regulations stipulate specific and technical issues based on the authority given to the ministries; for example, in the spatial planning and land administration sector, the technical regulations are issued by the Ministry of Agrarian and Spatial Planning/National Land Agency (Ministry of ATR/BPN), in the geospatial information by the Indonesian Geospatial Agency (BIG), in the sector of marine and fisheries by the Ministry of Fisheries and Marine Affairs (KKP), and in the sector of housing and development by the Ministry of Public Works and Housing (Kemen PUPR). Those technical regulations apply nationally, as they are issued by central governmental bodies and are legally binding as long as they have a chain of validity to the higher regulations (Presidential Regulations and above). Since the statutory tenure forms could spread across different levels of regulations and sectors, this study does not limit the identification of tenure to only one hierarchical level or one sector. However, for grouping purposes, the statutory tenure forms are still categorized based on land-based regulations and coastal-marine-based regulations.

3.3.1.1.1 Land-based regulations

Land tenure regulations

In Indonesian statutory land tenure system, the highest reference is Basic Agrarian Law (BAL/Act No. 5 of 1960) or in Indonesian terms, known as *Undang-undang Pokok Agraria* No. 5/1960 (UUPA) concerning Basic Regulations of Agrarian Principles. The Law was enacted to implement Article 33 of the Indonesian State Constitution (UUD 1945). According to Article 1 Paragraph 3 in BAL, the relations between Indonesians and land, water and space are eternal. Article 2 stipulates that land, water, and space, is governed by the state as an organization of all people in a right to

1. Regulate and operate allocation, use, supply, and maintenance,
2. Define and govern (regulate) legal relations between people with land, water and airspace,
3. Define and govern (regulate) legal relations between people and legal actions about land, water, and airspace.

BAL is generally considered an umbrella law governing land possession in Indonesia because it outlines the fundamental types of rights that may be held and sets out the role of the state in making regulations concerning the land (Gold and Zuckerman, 2014). BAL categorizes land rights in Indonesia into four types, resulting in 16 distinct formats of rights (Figure 11). (Please note that "rights" here refers to the tenure in the form of "title", not rights as the other name for "tenure forms").

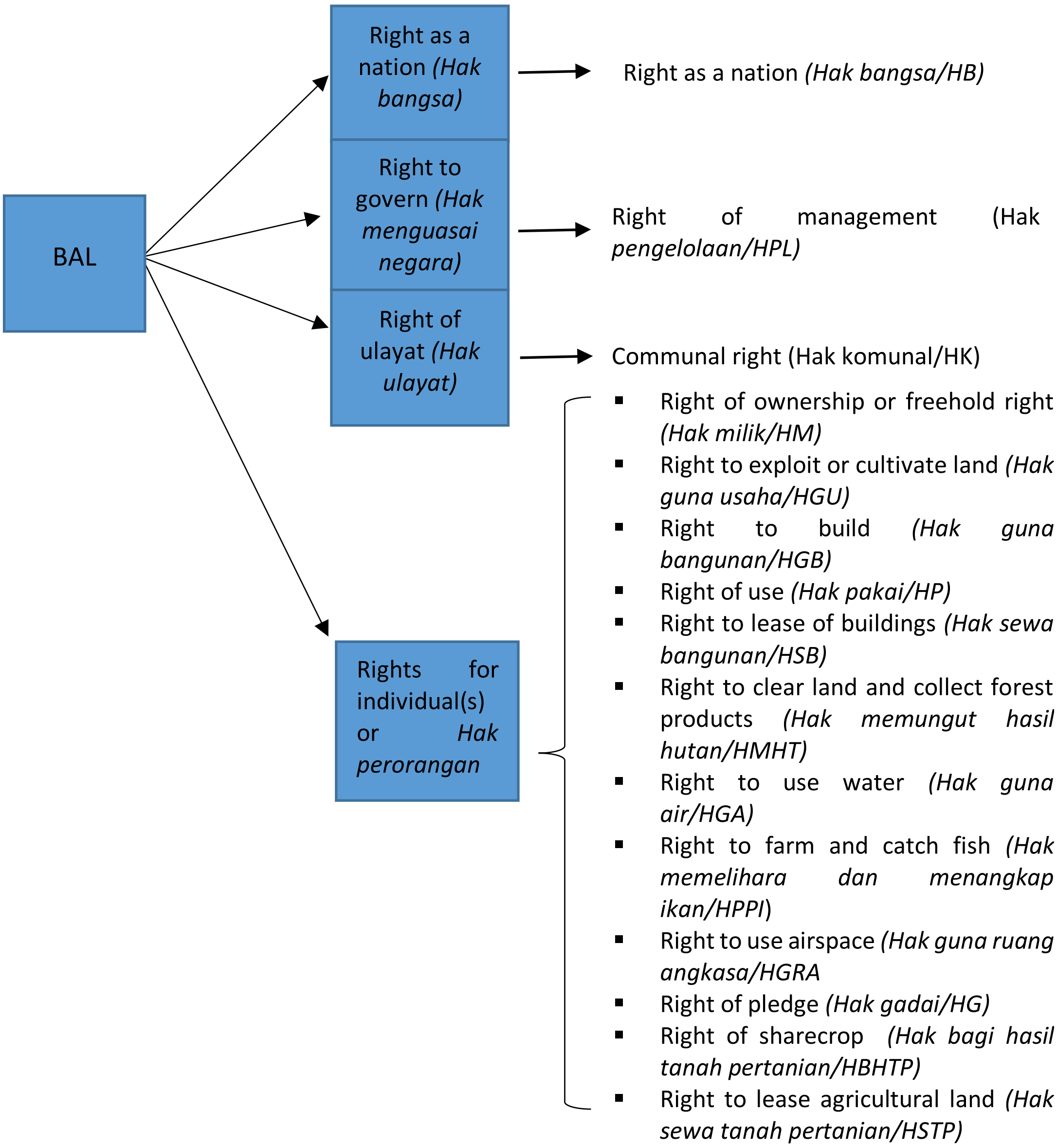


Figure 11. Land rights of BAL

The short description of every form of right is as below: (source: BAL, Governance Regulation No. 24 of 2007 on Land Registration, Government Regulation No. 40 of 1996 on HGB, HGU and HP (continued by Government Regulation No. 18 of 2021 concerning Management Rights, Land Rights, Apartment Units, and Land Registration), Minister of ATR/BPN No. 10 of 2016 concerning Procedures for Determining Communal Right for Land of Indigenous People and Land of Communities in Specific Areas)

1. Right as a nation (HB).
   Right as a nation/Hak Bangsa (HB) is an eternal legal relationship between Indonesia as a nation and the region where the nation exists. This means, as long as Indonesians who are united in the nation-state Indonesia still exist and as long as the land, water, and airspace of Indonesia still exist, in any circumstances, there is no power that can be able to break or negate the relationship.
2. Right of management (HPL).

HPL is a direct manifestation of *Hak bangsa*, which gives the state the power to govern and manage Indonesian land, water, and airspace. An individual, communities, and private sectors cannot have this right. Only the governmental bodies can hold it.

3. Communal right (HK).
   HK is the land right of a group of indigenous people or the rights of community groups in a particular area to own and use their lands for the purpose of improving their livelihoods.
4. Rights of ownership or freehold right (HM).
   HM is the land right granted to individuals or legal entities (i.e., government banks, social and religious bodies) to own a piece of land with limitless duration of ownership and without restrictions of any type of use and utilization.
5. Right to exploit or cultivate land (HGU).
   HGU is the land right to cultivate land controlled by the state for Indonesian individuals and companies specifically limited for agriculture, plantations, land fisheries, and livestock purposes within a certain period. HGU is arranged for middle- to large-scale possession.
6. Right to build (HGB).
   HGB refers to the legal entitlement of an individual or legal entity to possess land for the construction and operation of a building within a specific timeframe. People can use the building for a variety of purposes, including living houses, offices, stores, hotels, and any other service or commercial use. The land itself does not belong to the party holding the HGB.
7. Right of use (HP).
   HP is the right for individuals and institutions to use and reap the produce of the state-owned land or land owned by persons or legal entities for the purposes written in the certificates within a certain period or with unlimited time. The purposes vary depending on the necessity, from housing, cultivation, commercial uses, and other needs, as long as they do not go against the laws.
8. Right to lease of building (HSB).
   HSB is the right to use the other's property (land and the building) by leasing within a certain period.
9. Right to clear land and collect forest products (HMHT).
   HMHT is the right to use forest land other than protected and conservation zones.
10. Right to use water (HGA).
    HGA is the right to use water from rivers, streams, or water springs from the other party's land for the intention of irrigation and household needs.
11. Right to breed and catch fish (HPPI).
    BAL names the right clearly, but the law does not give a definition. Law No. 16 of 1964 on Fishery Product Sharing describes the right in two kinds: the right to use land for fish breeding and the right to catch fish in seawater.
12. Right to use airspace (HGRA).
    Right to use elements above the surface of the earth.
13. Right of pledge (HG).
    HG is the pawn right, which is occurring due to a pledge when a first party gives his land to the second party as a payment for his debt. The right ends when the first party has redeemed or returned a sum of money to the pawn holder.
14. Right of sharecrop (HBHTP).
    HBHTP is the right to cultivate/manage a plot of the farm belonging to another person with a provision that the profit will be shared between the cultivator/manager and the landowner.
15. Right of lodging (HMen).

It is the right to build and occupy a house on another person's land after obtaining permission from the landowner without paying rent.

16. Right to lease agricultural land (HSTP).
    HSTP is the right to cultivate another person's land by paying rent.

Although BAL points to Hak Bangsa as one of the types of land rights, it is essentially different from the other rights. Hak Bangsa functions as the proclamation of the eternal relationship between the Indonesian people as a whole and the Indonesian homeland, and hence, this right is a philosophical foundation for the establishment of other land rights (Santoso, 2010). According to that understanding, the selection of suitable tenure forms excludes Hak Bangsa. Besides Hak Bangsa, another right that is different from the other rights is HPL (Rahmi, 2010). According to Minister of ATR/Head of BPN regulation No. 9 of 1999 Article 1 paragraph 3, as a representation of *Hak Bangsa and Hak Menguasai Negara*, HPL is still the state's governing right (Parlindungan, 1998) and hence is often considered different for other rights (Harsono, 2008; Santoso, 2015). HPL is also only relevant to be held by the governmental bodies on a big scale (tens to hundreds of thousands of hectares) possession. This study excludes HPL for the occupation in coastline settlement areas but still open to the possibility that HPL can be relevant for the large areas outside the settlements such as military ports or shipping state-owned enterprises.

This study then shortlisted those identified tenure forms based on the operational status and suitability. The operational status shows whether the rights still function in statutory Indonesian land administration system and still exist in practice today in the term that those rights can be manifested and registered in the Land Office to get a certificate of rights as a proof of possession. Suitability means the fittingness of the forms for being applied in the coastline settlement areas. The tenure forms that are not operational would be absent from further analyses.

From the operational status, it is revealed that most of the land rights in BAL are currently non-operational. The first reason regarding this is because BAL itself has declared that several rights will be demolished after some years (Harsono, 2008). Those rights are Right of Pledge (Hak Gadai), Right of Lodging (Hak Menumpang, Right of Sharecrop (Hak Bagi Hasil Tanah Pertanian) and Right to Lease Agricultural Land (Hak Sewa Tanah Pertanian). The second is because, after the establishment of BAL, there are no derivative rules regarding some of those stipulated rights. As a result, those rights do not have a clear form of implementation. As the statutory rights rely upon their existence from the establishment of legislation as the basis of creation and continued existence, without further technical and concrete form, it can be said that the forms are void. An example of this case is Right to use airspace (Hak Guna Ruang Angkasa) and Right to use water (Hak guna air). These rights have never existed since the establishment of BAL. Santoso (2010) argues that the development of other sectoral laws (forestry, agriculture, etc.) causes this discontinuation from BAL side. It is important to note that while some tenures are not formalized as land titles, certain forms in BAL have evolved into alternative forms. Right to breed and catch fish (Hak Pemeliharaan dan Penangkapan Ikan), for example, today exists in the form of permit, and the regime controlling it no longer the one from the train of BAL but from the coastal marine sector. Right of lease of building (Hak Sewa Bangunan) is not given in the form or title any longer but has transformed into a form of letter/deeds.

The result of the investigation as below:

Table 8. Operational status of land rights from BAL

No.	Format of Rights	Operational status
1	Communal right (Hak komunal)	✓
2	Right of ownership or freehold right *(Hak milik)*	✓
3	Right to exploit or cultivate land *(Hak guna usaha)*	✓
4	Right to construct building *(Hak guna bangunan)*	✓
5	Right to use *(Hak pakai)*	✓
6	Right to lease of buildings *(Hak sewa bangunan)*	Ø
7	Right to clear land and to collect forest products *(Hak memungut hasil hutan)*	Ø
8	Right to use water *(Hak guna air)*	Ø
9	Right to farm and catch fish *(Hak pemeliharaan dan penangkapan ikan)*	Ø
10	Right to use airspace *(Hak guna ruang angkasa)*	Ø
11	Right of pledge *(Hak gadai)*	Ø
12	Right of sharecrop *(Hak bagi hasil tanah pertanian)*	Ø
13	Right to lease agricultural land *(Hak sewa tanah pertanian)*	Ø
14	Right of lodging *(Hak menumpang)*	Ø

Source: Author

Table 8 shows among those 16 identifiable tenure forms, only five tenure forms that are still operational, namely Communal right (HK), Right of ownership or freehold right (HM), Right to cultivate land (HGU), Right to construct building (HGB), and Right to use (HP).

Table 9. Suitability of the operational rights to aquatic lands

No	Format of Rights	Suitability
1	Communal right (HK)	✓
2	Right of ownership or freehold right (HM)	Ø
3	Right to exploit or cultivate land (HGU)	Ø
4	Right to construct building (HGB)	✓
5	Right to use (HP)	✓

This study argues that HGU and HM should be expelled during the suitability check (Table 9). HGU is considered not suitable because its implementation only takes place for middle to big scale agriculture purposes (>5 hectares). HGU can be assigned to some middle scale possession in the coast (i.e., land-side of a coastal area) like salt ponds and fish ponds, but not for small scale possession in coastal waters like "karamba fish" and "stilt bagan".

Specifically for HM, there are two different views regarding its suitability for aquatic lands, whether a parcel in coastline water areas can be owned, not just be occupied, by using a freehold right that can give full time and unlimited authority to the holder to use land. Sofyan (2016) agrees that freehold titles can be assigned for parcels in shore settlements. He bases his argument on the circumstance that, because settlements are indeed a dynamic type of land use as a living place for people with intermixed interests, and in order to ensure the maximum legal certainty of landholding, HM is therefore appropriate, regardless of the settlement's location.

As a contrary, Rais (2002b) argues that there should be no individual-full ownership in the sea water (either shallow or deep waters); only rights to access, use, and manage that apply. As stated by BAL, individual here points to the persons and legal entities. In his argumentation, Rais asserts that the possession on the basis of a right that gives full and "almost absolute" power to an individual or a legal entity to a piece of land in coastal waters is not permissible because the concept of marine governance, although recognizing the relationship between coastal people and their lands, only gives power to individuals to use instead of a right to own as the right to own is still attached to the whole Indonesian people following to the conception of Hak Bangsa. Moreover, that power to use (in whatever form) can only be given formally by the government, as said by Tamtomo (2006), as long as the use does not clash with public needs, for example, shipping line.

This thesis supports Rais' point of view and argues, because the main point is "power to use" and the word "use" is indicating a time limit (i.e., has certain period of usage), the most relevant rights for the individual possession in the aquatic lands (without reclamation) is type of rights that seize duration of occupations, and so, cannot be HM. HM still can be assigned to land in coastal areas, only for reclamation areas (when the waters being changed to lands) and coastal lands outside the protected area and the "sempadan pantai" area (the corridor area between the high tide line and 100-300 meter to the land side: Presidential Regulation No. 51 of 2016 concerning The Sempadan Pantai Boundary)

However, when the concept of individual ownership is not appropriate to aquatic lands, we argue that the concept of communal ownership of HK (Rachman, 2016), in the opposite, with respect to their long history and tradition of residence, should be fitted with aquatic lands occupied by indigenous people and traditional communities. Hence, besides HK, the suitable rights for parcels in coastline areas for individuals are the ones that have a duration of occupations, namely HGB and HP. According to Government Regulation No. 40 of 1996 on HGB, HGU and HP (continued by Government Regulation No. 18 of 2021 concerns Management Rights, Land Rights, Apartment Units, and Land Registration) and Law No. 25 of 2007 concerning investment, in the coastal areas (which is commonly categorized as free state-lands or as community lands if apply) HGB can be given to individuals for 30 maximum years in the 1st assignation (Indonesian: pemberian hak), can be extended for the 2nd period for the next 20 years ("Indonesian: perpanjangan hak"), and finally can be renewed for the next 30 years maximum (Indonesia: pembaharuan hak). According to Government Regulation No 18 of 2021, HP can be given to individuals for maximum 30 years for pemberian hak, 20 years for perpanjangan hak, another 30 years for pembaruan hak. This type of HP is called "Hak Pakai Privat" of HP for Private Affairs. However, for the usage by any government organization for govermental affairs (for office buildings, for instance) and religious body (for mosques, churches, etc.) HP can be given following the necessity, meaning no time limit of use. This mode is called "Hak Pakai Publik atau Hak Pakai Khusus" or HP for Public Affairs/HP for Specific Purposes (Santoso, 2010).

Housing and settlement regulations

Unlike in BAL which is indeed the main source of regulation for managing statutory land rights in Indonesia that could give various type of rights, in housing and settlement sector, we found only one operational and applicable tenure forms based on formal leases/contractual leases or Sewa Kontrak (SWK). This tenure form is stipulated in Law No. 4 of 1992 on Housings and Settlements and Government Regulation No. 44 of 1994 on House holding by Non-Owners. This type of tenure is internationally similar to the concept of "leasehold tenure" which provides an opportunity for tenants to physically use and occupy a property in certain periods of time and conditions.

In this system, the lease is made under legal contract from the public notary and hence, the possession transfer is formalized and has a legal binding and consequences in case of a violation of the agreement. The tenants have rights to physically use the property for their own purposes (household, commercials, offices, etc) with certain obligations (i.e., pay the rent, maintain the building) in certain period written in the contract documents, but has no right of ownership. The owner of the parcel and building still keep the tenure. The tenants also do not have a right to transfer their leasing occupation to the third party except there is a prior agreement says otherwise. The field observation showed this kind of tenure forms are common in Kamboja and Tanjungpinang Kota, two urbanized coastline settlements in Tanjungpinang.

3.3.1.1.2 Coastal-marine based regulations/spatial planning regulations

Location Permit/*Izin Lokasi* dan Utilization Permit/*Izin Pemanfaatan* (IL/IP)

In Law No. 27 of 2007 on the Management of Coastal Areas and Small Islands, followed by Law No. 1 of 2014 on the Amendment of Act No. 27 of 2007 and then in Regulation of the Minister of Marine Affairs and Fisheries Number 54/PERMEN-KP/2020 concerning Location Permits, Management Permits, and Offshore Location Permits, we found the operational and applicable formal tenure in the form Location Permit/*Izin Lokasi* dan Utilization Permit/*Izin Pemanfaatan* (IL/IP Permit) for aquatic lands. Following the latest regulation development, IL and certain aspects of IP has been transformed into Conformity of Spatial Utilization Activities (KKPR) by Law No. 6 of 2023 on the Stipulation of Government Regulation in Liew of Law No. 2 of 2022 on Job Creation into Law and Government Regulation No. 21 of 2021 about Implementation of Spatial Planning. As a pre-permit for utilizing land, KKPR can be applied for land area and marine areas. Conformity of Marine Spatial Utilization Activities (KKPR Laut) is stipulated further by and in the Minister of Marine Affairs and Fisheries Regulation No. 28 of 2021 on the Implementation of Marine Spatial Planning. The IL/IP that previously has been issued emains valid until its expiration based on the designated holding period. For convenience, this thesis still uses IL/IP as the term, and in few occasion, we will use add the term KKPR if necessary.

The Law defines that IL is a permit given by the authorities to occupy the space of the coastal waters and small islands. IP is a permit to manage coastal and small islands' resources for specific purposes stipulated by law. As IL usually directly followed by IP (IL can be expired within 2 years if the holders do not proceed the permit into IP), both are usually considered as a bundle form of tenure possession instead of two different forms. IL/IP permit has a certain duration of occupation and maximum size area. IL/IP can be given to individuals, corporations, cooperatives, and local and traditional community. Law No. 1 of 2014 defines the local community as a group of people whose daily living are run on the habits from the accepted values but are not entirely dependent on coastal resources and small islands. Traditional communities are traditional fisheries communities whose traditional rights for fishing activities and other legitimate activities in certain areas within archipelagic waters are acknowledged in accordance with the rules of international marine law.

***Surat Pembudidayaan Ikan* (SPI) or Permit on Fish Breeding Activities**

In Riau Islands, according to Riau Islands Province Regulation No. 6 of 2006 on Fisheries Activities in Riau Island Province, the government issues a permit for individuals or fishing companies to occupy and utilize a certain area in coastal waters for fisheries activities such as breeding, spawning, and aqua-culture cultivation. The permit is called Surat Pembudidayaan Ikan (SPI) or Permit on Fish Breeding Activities. This permit has a certain duration and can be extended. The subject of the regulation is individual fishermen, fishing community groups in the form of cooperatives or fisheries companies. The regulation was strengthened by the Tanjungpinang City Regulation No. 7 of 2012 concerning Specific Licensing Levies.

3.3.1.2 Non-statutory tenure forms

Informal or non-statutory tenure forms are the forms which are not governed by the existing regulations and often based on traditional and locally relevant rules about how to allocate land to the intended party and usage. Parallel with the questionnaire interview activity, during the field observation, we had identified several informal tenure forms. Those forms are described briefly in the following paragraphs.

Numpang Bangun (NB) system

"Numpang" and "bangun" is loosely translated as "to stay" and "to build". *Numpang Bangun* (NB) is a system of landholding where the land is shared by the community to a member for housing purpose. The system is common in traditional and small coastline villages Klam Pagi, Dendun Island, Dompak Darat, Madong, and Sebaok where most of the villagers come from the same bloodline. If a newly married man needs to build a living house for his family, he deserves to possess a piece of land by just asking the other family members and the community elders. He is not requested to buy the land or put some amount of money as compensation of contribution to the community. In the previous era, the permission is mostly given orally, just based on the verbal agreement. Today most of the agreements are made on papers containing a written agreement to occupy a piece of land from the elder of the family. Although through this system, the person who holds the given land can occupy it as long as needed and he has the right for the house he builds, the right of the land itself belongs the community. The new occupant also has no right to change to the utilization of the building to the purpose other than for living house.

Tenure based on Grant (GR)

Grant or also known as Sultanate Grant, is a old letter issued by the governing authority (Malay Kingdoms or Dutch colonials) before the independence of Indonesia in 1945 recognizing that the Grant holder (usually a loyal individual, can be a royal family member or ordinary individual/"kaula swapraja") is the person who possesses the land and has any rights towards the land (Hanafiah, 2016). Grant holding system is common in all area of Riau Islands and in the eastern part of Sumatera Island (Mahadi, 1976). The language written in the letter is Malay-Arab characters. The letter gives power to the holder to occupy and use the land in a very large size in comparison to nowadays occupancy, ranging from tens to thousands of hectares, from the inland to the coastline areas. The main purpose of land holding is for agricultural field and forest resources extractions (including mangrove). Although this form of tenure holding is making controversy because of the denial from the other member of modern society, today people still can found the occupation claim based on this type of tenure form in Sebaok and Senggarang, in the northern coastal part of Tanjungpinang.

Informal leases or Sewa Bawah Tangan (SWBT) system

SWBT is a system of landholding that relies on the tenancy process as a basis for possession. However, unlike SWK, under this system, there is no paper-based contract from a public notary between the tenants and the holders. The agreement was only made based on the trust between both parties. Although the landholder owns the land, usually it is the tenants who build the house (normally the building is non-permanent). It means, while the land parcel belongs to, for example, A, the house itself belongs to B or C. Because of that situation, we can say that the system clearly indicates the separation between two traits of possession, which is called in Santoso (2010) as the physical possession and juridical possession. In juridical possession, the landholders can both physically use and juridically hold the land, and also can transfer their physical possession to others. In physical tenure, the landholder only can physically use the land without having a juridical possession. The field observation reveals that this informal lease system occurs in Tanjung Unggat and Melayu Kaca Piring villages.

Tenure based on Surat Tebas/Tebas Tebang (ST) or Letter to Slash

Surat Tebas is an old statement paper given by the hamlet (small village) head in the period around 1960 to late 1990. The paper permits the member of the village to access and clear the land (for example, shore vegetation) for certain purposes including fishery activities and erect buildings. The size of the are is uniform, 2 hectares for each individual as it is more likely a form of land distribution activity where each member of the community obtains the same size of the plot. This type of tenure claim is common in practice in Riau Islands. In the study area, although the letter is no longer issued by the head of the hamlets (e.g., replaced by the establishment of SKT), in practice, we observed that the landholding by means of this type of tenure still exists in the transition areas between traditional and urban settlements in Senggarang Besar and Dompak Darat villages.

Tenure based on *Surat Keterangan Tanah/Surat Kepemilikan Tanah* (SKT) or Letter to Prove the Possession

SKT is a generic name for a statement letter from the head of the village where the land is located showing that an individual whose name is written in the letter is the person who is entitled to occupy the land. The letter also details the land's ownership history. In Riau Islands, different regions will have different names. In Batam, Tanjungpinang, and Bintan, the letter is called SKT, whereas in Jemaja coastal village, Anambas Island, it is called Surat Keterangan Penguasaan Tanah (SKPT)/Land holding letter and Surat Keterangan Pemilikan Rumah (SKPR)/Housing letter. SKT can be considered the modern version of Surat Tebas, and usually, the locals who previously had Surat Tebas will change it into SKT when necessary. Compared to Surat Tebas, it has stronger claims over the land because there is also a field check by the village officials. SKT is originally a custom based letter (the content depending on the necessity of the village), but nowadays, due to the requirement to provide an administrative prerequisite letter for any actions regarding to the land, for example, transaction, the letter is made official and standardized by the village administration by issuing a local regulation (in Indonesia: "Peraturan Desa"). Therefore, to some degree, this SKT can be considered as a semi-formal tenure form. The field observation found land holdings by SKT (with names) in every coastline settlement we had visited.

3.3.1.3 Summary

Table 10 below shows the results of tenure forms identification:

Table 10. Summary of potential tenure forms to be applied for aquatic lands

No	Ttenure forms	Category	Source of tenure	Format of recognition	Party that issue the proof of tenure
1	HP	Statutory	BAL 1960 (Land tenure and derivative regulations)	Paper based (title)	Land Office
2	HGB			Paper-based (title)	Land Office
3	HK			Paper-based (title)	Land Office
4	SWK		Housing and settlement regulations	Paper-based (deed/contract)	Public Notary Office
5	IL/IP (KKPR)		Coastal marine regulations/spatial planning regulations	Paper-based (pre-permits)	Govermental bodies
6	SPI			Paper-based (permit)	Regent/City Mayor
7	NB system	Non-statutory	Traditional	Oral-based or paper-based (letter)	Head of the community
8	GR (Grant)		Malay Sultanate and Dutch colonial era	Paper-based (letter)	Sultan (The King), Dutch colonial governor
9	ST		Old local administration	Paper-based (letter)	Head of the hamlet
10	SWBT system		Local customs	Oral-based	Agreement from both sided (tenants and owners)
11	SKT		Local administration	Paper-based (letter)	Head of the village administrative, authorized by the head of subdistrict

From Table 10, it is evident that the format of recognition, source of tenure, and the issuing agents are diverse for tenure forms. Statutory forms' format of recognition is paper-based titles, deeds, or permits, reflecting a formal and documented approach. Non-statutory systems use oral agreements or paper-based letters issued by community leaders. The source of tenure of statutory forms is typically originates from the regulations enacted by the government, whereas non-statutory tenure usually stems from traditional or non-governmental systems. The issuing agents for statutory forms are government bodies (i.e., the Land Office or regional authorities) while for non-statutory forms are often facilitated by the traditional or local figures, like heads of communities. This variation leads to a spectrum of tenure, as illustrated in Figure 12 below.

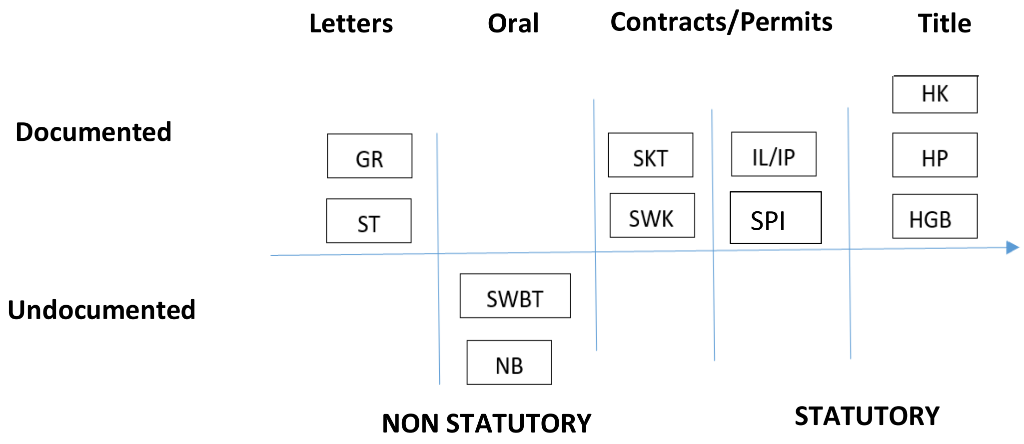


Figure 12. Spectrum of tenure

Table 11 shows the eligible subjects for the tenure forms we identified from the regulations and field discussions.

Table 11. Eligible subjects for aquatic land tenure forms.

No	Subjects	Tenure forms										
		HP	HGB	HK	SWK	IL/IP	SPI	NB	GR	ST	SWBT	SKT
1	Individuals											
	▪ Indonesian	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓
	▪ Foreigners domiciled in Indonesia	✓										
2	Indonesian local communities/Indonesian traditional communities/indigenous groups	✓		✓		✓	✓					
3	Indonesian legal entities (established under Indonesian law and domiciled in Indonesia)											
	▪ Private company	✓	✓		✓	✓						

Table 11 (continued)

	▪ State-owned enterprises (BUMD) or regional-owned enterprises (BUMD)	✓	✓		✓	✓						
	▪ Cooperatives					✓	✓					
4	Government agencies	✓				✓						
5	Foreign legal entities that have a representative in Indonesia and established under Indonesian law	✓	✓			✓						
6	Religious body (religious foundation)	✓			✓	✓						✓
7	Social bodies (social foundations)				✓	✓						✓
8	Representatives of foreign countries	✓										
9	Representatives of international bodies	✓			✓	✓						

3.3.2 Multi-criteria decision analysis to select the optimum tenure forms

Decision-making is the procedure to discover the best alternative among a set of feasible alternatives (Wang and Lee, 2007). When involving multiple criteria, the procedure is called Multiple-criteria Decision Analysis (MCDA) or called Multiple-criteria Decision Making (MCDM) (Majumder, 2015). In general, there are two steps for solving decision-making problems, which are making a rating on each alternative based on the aggregation of degrees of compatibility of all criteria and ranking all alternative to get the best alternative (Kusumadewi et al., 2006)

As mentioned earlier, in this thesis, the multi-criteria decision analysis techniques used to select the optimum tenure forms is a combination of Analytical Hierarchy Process (AHP) and Fuzzy Technique for Order Performance by Similarity to Ideal Solution (Fuzzy TOPSIS). Fuzzy TOPSIS is the TOPSIS method that is developed to anticipate the decision making in the fuzzy environment, which is normal, when the source of information is based on the human's perception. The usage of this combination is beneficial as the AHP method can provide the quantitative weight of the subcriteria that will be used in the Fuzzy TOPSIS method to evaluate the tenure forms to get the most optimum one. With the resulted quantitative weights that suggest the rank, the AHP can also give information about the respondents' preference, which in this topic is regarding the kind of secure tenure situation. As far as we are aware, the combination of the methods we approach in this thesis is never been used previously to select the optimum land tenure forms. Amiri (2010), Agrawal, Singh, and Murtaza (2016), Muhardono and Isnanto (2014), Dagdeviren, Yavus, and Killinc (2009) had deployed the combination for addressing other problems (i.e., oil project selection, product disposition, candidate selection for promotion, and weapon selection).

3.3.2.1 AHP analysis

3.3.2.1.1 Concept

Analytical Hierarchy Process (AHP) is a method developed by Prof. Thomas. L. Saaty from the University of Pittsburgh in the 1970s and has been extensively used and studied since then to solve decision-making problems. Saaty (1980, 2000) states that in solving the problems, AHP transforms a complex situation into several components in a hierarchical arrangement. The hierarchy is structured into the number of levels required to fully characterize a particular decision situation. AHP can also be considered a form of modeling whose input normally comes from the opinions or perceptions of people who are competent or related to the topic and problems that needs a solution (Bozbura et al., 2007). The sampling source is then purposive: the target respondents had been determined previously and they should be competent with the case to be studied. There is no statistical requirement for the number of samples. In the judgment making, AHP conducts pairwise comparisons of alternatives in a questionnaire. The ability to deal with decision problems involving prejudiced judgments, number of decision makers, and the preference consistency make the method a constructive approach (Triantaphyllou, 2000; Baby, 2013) to represent and quantify its elements and for evaluating alternative solutions (Majumber, 2015).

3.3.2.1.2 Steps

Three main principles of AHP are decomposition/hierarchy arrangement, comparative judgment and synthesis, and logical consistency (Saaty, 1980, 2000). Decomposition/hierarchy arrangement is the systematic step to describe the problem into a structured hierarchy. Although the hierarchy can be at various level, in general, it consists of goals, criteria, and options. Comparative judgments are the activity to conduct pairwise comparisons of the alternatives based on their relative importance (Table 12). Synthesis of the priorities is aiming to rank the alternatives based on the weights. Logical consistency step checks the consistency of the pairwise comparison judgments.

In this research the AHP analysis followed the stages:

1. Decomposition and hierarchy arrangement (Figure 13) .
   In general, the formed hierarchy is:

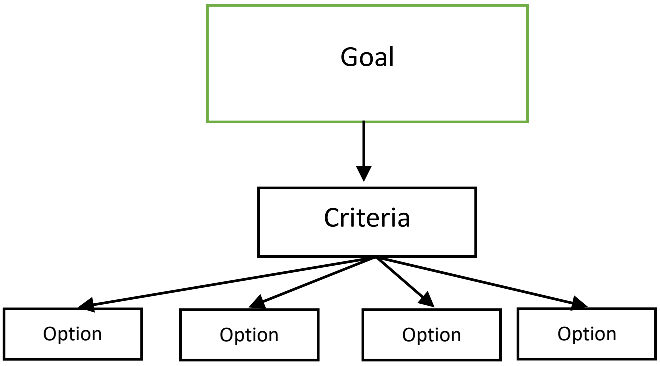


Figure 13. Hierarchy of AHP for each criteria.

   which is formed for each criteria.
   Note:
   Goal : to determine the preferred secure situation.
   Criteria and Option is referring to Table 7.

2. Comparison judgment and synthesis.
   Stages in comparison judgment and synthesis:

   a. Creating an evaluation matrix for every criteria (i.e., convenience of using land, recognition, and so on).

      Let C = $C = \{C_j | j = 1,2, \dots, n\}$ be the set of option. The result of pairwise comparison of *n* option, can be summarized in an (*n* x *n*) evaluation matrix A in which every entry/element a_{ij} (i,j = 1,2,…, n) is the quotient of weights of the criteria. The entry is the value based on the score of relative importance from the questionnaire.

      As the study has multiple respondents, a_{ij} is taken from the geometric mean (GM) of the entries from all respondents, which the GM can be calculated by

$$GM = \sqrt[n]{(X_1)(X_2)\dots(X_n)} \quad \text{(eq. 1)}$$

Where:

GM = geometric mean for each entry

X_1 = 1st respondent judgment

X_2 = 2nd respondent judgment

X_n = nth respondent judgment

Matrix A:

$$A = \begin{bmatrix} a_{11} & \dots & a_{12} & \dots & a_{1n} \\ \vdots & & \vdots & & \vdots \\ a_{21} & \dots & a_{22} & \dots & a_{2n} \\ \vdots & & \vdots & & \vdots \\ a_{n1} & \dots & a_{n2} & \dots & a_{nn} \end{bmatrix} \quad a_{ij} = 1, a_{ji} = \frac{1}{a_{ij}}, a_{ij} \neq 0 \quad \text{(eq. 2)}$$

Table 12. Pair-wise comparison scale (modified from Saaty, 1980)

Numeric value (intensity of importance)	Meaning	Explanation (compare option 1 and 2)
1	Equally importance	Two options are equally preferred
3	Moderately importance	One option is moderately preferred over another
5	Strongly importance	One option is strongly preferred over another
7	Very strong importance	One option is preferred very strongly over another
9	Extremely importance	One option is completely preferred over another
2,4,6,8	Intermediate values	The grades that can be used to express intermediate values used to represent compromises between the adjacent intensity/judgments

b. Normalizing the matrix A.

Once the matrix A is built, it is possible to derive from A the normalized pairwise comparison matrix A_{norm} . Let $\bar{a}_{ij}$ be the normalized entry for A_{norm}. The $\bar{a}_{ij}$ can be calculated by dividing the a_{ij} with the sum of each column.

$$\bar{a}_{ij} = \frac{a_{ij}}{\sum_{i=1}^{n} aij} \qquad \text{(eq. 3)}$$

c. Calculating weights vectors or eigen vectors.

It was conducted by averaging the entries on each row of A_{norm}

$$w_{ij} = \frac{\sum_{j=1}^{n} \bar{a}_{ij}}{n} \qquad \text{(eq. 4)}$$

In the matrix format, W

$$W = \begin{bmatrix} w_{11} \\ w_{21} \\ w_{n1} \end{bmatrix} \qquad \text{(eq. 5)}$$

3. Calculate consistency ratio (CR).

With many pairwise comparisons, some inconsistencies may typically arise. The AHP incorporates a technique for checking the consistency of the evaluations made by the decision makers when building each of the pair-wise comparison matrices involved in the process.

There are steps to check the consistency:

a. Calculate the consistency measure/consistency vector (CV) by multiplying the Matrix A by the weights vector matrix (W) to obtain weighted sum vectors, then divide the weighted sum vectors by the corresponding weight vector.
b. Compute the average of CV, denote it as λmax.
c. Calculate Consistency Index (CI). CI measures the deviation.

$$CI = \frac{\alpha_{max} - n}{n-1} \qquad \text{(eq. 6)}$$

d. Calculate the consistency ratio (CR).

$$CR = \frac{CI}{RI} \qquad RI = random\ index \qquad \text{(eq. 7)}$$

RI is the consistency index when the entries of A are completely random. The values of RI for small problems $(n \leq 10)$ are shown in Table 13.

Table 13. RI values

n	2	3	4	5	6	7	8	9	10
RI	0	0,58	0,90	1,12	1,24	1,32	1,41	1,45	1,51

Source: Saaty (1980)

A consummately consistent decision should always obtain *CI* = 0, but if CR < 0,10, the inconsistencies are tolerable, and a reliable result may be expected from the AHP. If this ratio is > 0,10, then the judgments are not consistent enough and the best thing to do is rechecking the input from the questionnaire answers and revising the comparisons.

4. If the CR is tolerable then we use the weight vectors as the weight of the option.

The whole process of AHP analysis is shown in Figure 14:

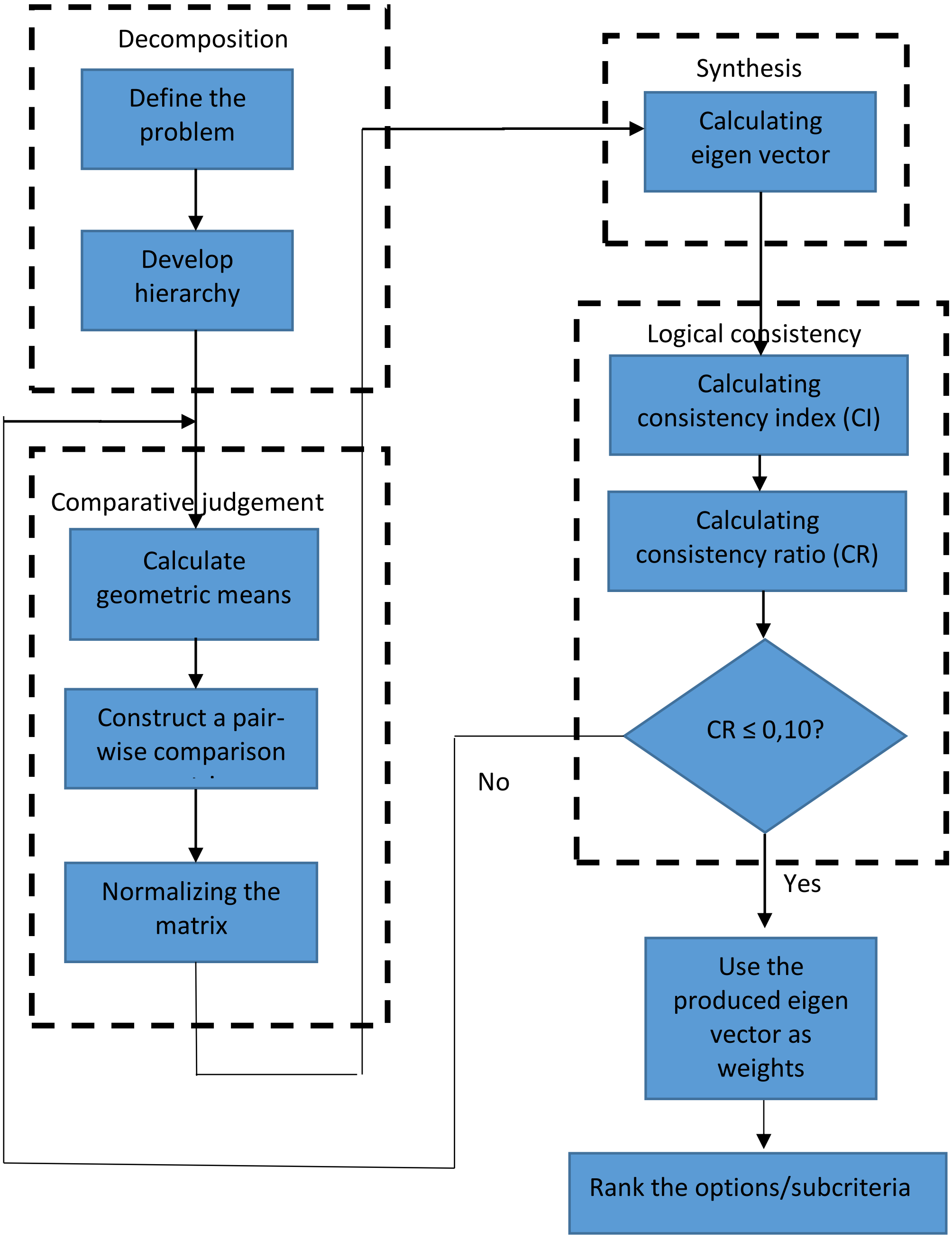


Figure 14. AHP analysis flowchart

3.3.2.1.3 Results: preferred tenure security situation

To each criteria, we asked the respondents to assign a number from 1 to 6 (as the total number of the criteria is 6). Every criteria could only be given a different number. Score 6 is considered as the most important criteria, and score 1 is the least important. In the calculation, the normalized weights (the sum of each criteria's score divided by the total score for all criteria) is presented in Table 14:

Table 14. Weights for the criteria

No.	Criteria	Weights
1	Convenience in using land (A)	0,15400
2	Convenience in transferring land (B)	0,13043
3	Duration (C)	0,13557
4	Accessibility and opportunity (D)	0,16932
5	Recognition (E)	0,20629
6	Security (F)	0,20438

From the AHP analysis (Appendix 3), the calculation results of the consistency check are shown as below:

Table 15. Consistency check results

Item	**Criteria**					
	A	**B**	**C**	**D**	**E**	**F**
λmax	4,00550	3,07276	3,10603	3,05126	3,04328	2,00000
CI	0,00183	0,03638	0,05301	0,02563	0,02164	0,00000
CR	0,00204	0,06272	0,09140	0,04419	0,03731	0,00000
	CR < 0,10 (Consistent) n = 4, RI = 0,9	CR < 0,10 (Consistent) n = 3, RI = 0,58	CR < 0,10 (Consistent) n = 3, RI = 0,58	CR < 0,10 (Consistent) n = 3, RI = 0,58	CR < 0,10 (Consistent) n = 3, RI = 0,58	CR < 0,10 (Consistent) untuk n = 2, RI = 0,00

Table 15 reveals that after some screening process and confirmations to several respondents in case of ambiguous answers, all AHP analysis presented consistency and therefore, we could use the produced eigen vectors as the weight of subcriteria (option). The weights of subcriteria from AHP analysis (i.e., AHP weight) can be seen in Column 2 of Table 16. The AHP weight of each subcriteria is not automatically comparable to other AHP weight from different criteria. It is because the AHP analysis was only generated inside every criteria. The total number of subcriteria in a particular criteria is also not always equal to another criteria's (Criteria A has 4 subcriteria, B-C-D-E have 3, and F has just 2) that makes every subcriteria in A has portion as many as 1 : 4 = 0,25, whereas in B-C-D-E = 1 : 3 = 0,3333, and in F = 1 : 2 = 0,50 (Column 3). To make the subcriteria's weight comparable across criteria, we need two things: deploying "linking weights" and doing a normalization to equalizing the portion. The linking weights are the weight of the criteria (Column 1). The normalization will give the proportion weight, which is obtained by dividing the number of subcriteria in a particular criteria by the total number of subcriteria of all.

As an illustration, for Criteria A the number of its subcriteria is 4. Given that the total number of all subcriteria is 18, the proportion weight for subcriteria in Criteria A is then 4/18 = 0,22222. For Criteria F with two subcriteria, the proportion weight is 0,11111. Using the given proportion weight, the portion of all A's subcriteria now will becoming 0,22222 x 0,25 = 0,05556. The portion of B-C-D-

E's is then 0,16667 x 0,33333 = 0,5556. For Criteria F it is 0,11111 x 0,50 = 0,05556. Having this equality, the subcriteria is now comparable to the others because all of them already have the same portion. Finally, to get the real comparable weight (final weight), the AHP weight of subcriteria should be multiplied by the proportion weight and by the weight of criteria. Based on the final weight, the ranking is determined and the list is presented in Table 17.

Table 16. Weight and ranking of the subcriteria

Criteria's weight		**AHP weight***			**Proportion accross citerion**	**Final weight of the subcriteria**	**Ranking**
(1)		**(2)**		Portion relative to criteria **(3)**	**(4)**	**(5) = (1) x (2) x (4)**	**(6)**
A	0,15400	A1	0,32842	0,25	0,22222	0,0112395	8
		A2	0,34597	0,25		0,0118401	5
		A3	0,19001	0,25		0,0065028	14
		A4	0,13559	0,25		0,0046392	16
B	0,13043	B1	0,53106	0,33333	0,16667	0,0115443	7
		B2	0,33010	0,33333		0,0071758	12
		B3	0,13884	0,33333		0,0030181	18
C	0,13557	C1	0,57121	0,33333	0,16667	0,012907	1
		C2	0,27949	0,33333		0,0063153	15
		C3	0,14930	0,33333		0,0033736	17
D	0,16932	D1	0,32422	0,33333	0,16667	0,0091494	11
		D2	0,25049	0,33333		0,0070688	13
		D3	0,42529	0,33333		0,0120016	4
E	0,20629	E1	0,37102	0,33333	0,16667	0,0127565	2
		E2	0,33933	0,33333		0,011667	6
		E3	0,28966	0,33333		0,0099592	10
F	0,20438	F1	0,55033	0,50	0,11111	0,0124974	3
		F2	0,44967	0,50		0,0102115	9

* AHP weight = the weight of the subcriteria within the corresponding criteria resulted from AHP analysis

Table 17. Preferred secure situation subcriteria (ordered from the first to the last)

Ranking	**Preferred secure situation (in subcriteria level)**	**Criteria**
1	Unlimited time of occupation (C1)	Duration
2	Administrative recognition in a residence card or other administration documents (E1)	Recognition
3	No fear of/minimum/no evictions and land expropriation (E1)	Security
4	Easier access to get developmental supports/aid (e.g., electricity, clean water, road infrastructure, public buildings, fishing facilities, etc.) from the government/other institutions (D3)	Accessibility and opportunity

Table 17 (continued)

5	Convenience to use the land for housing (A2)	Convenience in using land
6	Recognition in the legal documents of the land (e.g., certificates, permits, deeds, contracts) by the tenure authoritative bodies (E2)	Recognition
7	Convenience of inheritance (B1)	Convenience in transferring land
8	Convenience to use the land for various type of usage (A1)	Convenience in using land
9	No fear of/minimum/no of potential disputes (F2)	Security
10	Recognition by neighborhoods (E3)	Recognition
11	Higher possibility to access credit from bank/financial institutions (D1)	Accessibility and opportunity
12	Convenience in transactions with Indonesian (B2)	Convenience in transferring land
13	Higher prices in transactions and compensation (D2)	Accessibility and opportunity
14	Convenience to use the land for aquaculture activities (A3)	Convenience in using land
15	Long period of occupation and usage (>10 to until the maximum period allowed by the regulations) (C2)	Duration
16	Convenience to use the land for commercials buildings (A4)	Convenience in using land
17	Short period of occupation and usage (max 10 years) (C3)	Duration
18	Convenience in transactions with foreigners (B3)	Convenience in transferring land

3.3.2.2 Fuzzy TOPSIS analysis

3.3.2.2.1 Concept

TOPSIS is a technique that works by ordering preferences by the similarity of ideal situation. For doing so, TOPSIS defines an ideal solution and a negative ideal solution in order to obtain the optimal alternative. Wang and Lee (2007, p. 1763) explain that the ideal solution is the solution that maximizes the benefit criteria and minimizes the cost criteria and is composed of all of best values attainable of criteria. The negative ideal solution is the solution that maximizes the cost criteria and minimizes the benefit criteria; it consists of all worst values attainable of criteria. The optimal alternative is the one that is closest to the ideal solution and farthest from the negative ideal solution (Wang and Elhag, 2006).

In the traditional formulation of TOPSIS, personal judgments to select the best alternative are normally represented with crisp values. However, assigning values using a crisp number for judgments based on human perception is not always straightforward, because the criteria and subcriteria used are various and the perceived information always contains uncertainty. The uncertainty might come from the qualitative nature of the alternatives, incomplete and unclear available information provided to the decision maker, non-obtainable information, the decision maker's ambiguities, and other uncertainty and fuzzy situations (Kusumadewi et al., 2006; Kulak et al., 2005). To anticipate this fuzziness data situation, the concept of a fuzzy set from Zadeh (1965) was utilized by Chen (2000) and the method then so-called Fuzzy TOPSIS. In this thesis, the fuzzy approach will be used to anticipate qualitative information or interpretative information from the grey literature, which we took as a source for evaluating the applicability of the suitable tenure forms. Fuzzy TOPSIS produces a ranking sequence that is more consistent although alternative choices and new criteria are added (Junior et al., 2014). It also has been verified that modeling with fuzzy numbers is an effective way to formulate problems, where available information is subjective and not fully accurate (Rouhani et al., 2012).

Important basic understanding of Fuzzy TOPSIS:

1. Fuzzy set.
   Fuzzy set (i.e., a group that represents a certain condition a fuzzy variable) has two types of attributes, namely linguistic attributes and numerical attributes (Kusumadewi, 2013). The linguistic attribute is a group name that represents a certain condition or condition using natural language that is commonly used everyday (for example: very good, good). The linguistic variable is useful in dealing with situations which are too complex or too ill-defined to be reasonably described in conventional quantitative expressions (Zadeh, 1975). The numerical attribute is a number that indicates the value of a variable (examples: 0, 0,5, 1, 10). In addition, there is also another important main component in a fuzzy environment called membership function. The membership function is a curve that shows the mapping of input data points into its membership value which has range according to its universe of discourse (i.e., values that are allowed to be operated in a fuzzy variable) from 0 to 1.
2. Triangular Fuzzy Numbers.
   One type of membership functions is Triangular Fuzzy Number (TFN), where the membership function's graph forms a triangle with the 0X-axis (see Figure 15). This study uses TFN for fuzzy TOPSIS because it is intuitively easy for the decision-makers to use and calculate (Amiri, 2010). In practical applications, TFN is used most often for representing fuzzy numbers (Xu and Chen, 2007). Modeling using TFN has been proven to be an effective way for formulating decision problems where the available information is subjective and imprecise (Chang et al., 2007; Chang and Yeh, 2002; Zimmerman, 2001).

   A TFN $\tilde{A}$ = (a_1, a_2, a_3) is called triangular fuzzy number if its membership function is given by

$$\mu_{\tilde{A}}(X) = \begin{cases} 0 & x < a_1 \\ \frac{x-a_1}{a_2-a_1} & a_1 < x < a_2 \\ \frac{x-a_3}{a_2-a_3} & a_2 < x < a_3 \\ & x < a_3 \end{cases} \qquad \text{(eq. 8)}$$

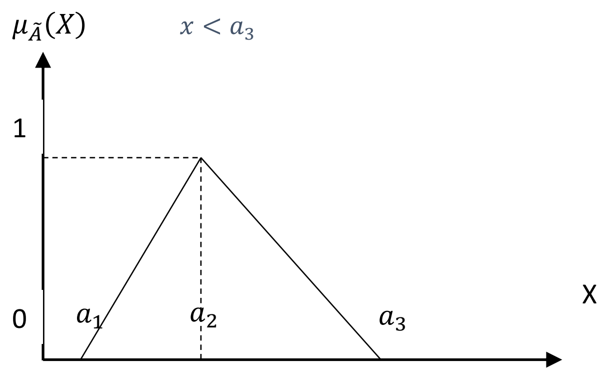


Figure 15. Triangular Fuzzy Number

in which a_1, a_2 and a_3 are real numbers with $a_1 < a_2 < a_3$. Outside the interval [a_1, a_3], the pertinence degree is null, and m represents the point in which the pertinence degree is maximum.

3. Algebraic operation.

Let $\tilde{A}$ and $\tilde{B}$ be two triangular fuzzy member parameterized by the triplet (a_1, a_2, a_3) and (b_1, b_2, b_3), respectively. The mathematical operation of these triangular fuzzy numbers are as follows (Amiri, 2010; Junior et al., 2014):

a. Addition

$$\widetilde{A}(+)\tilde{B} = (a_1, a_2, a_3)\ (+)\ (b_1, b_2, b_3) = (a_1 + b_1, a_2 + b_2, a_3 + b_3) \qquad a_1 \geq 0, a_2 \geq 0 \qquad \text{(eq. 9)}$$

b. Substraction

$$\tilde{A}(-)\tilde{B} = (a_1, a_2, a_3)\ (-)\ (b_1, b_2, b_3) = (a_1 - b_1, a_2 - b_2, a_3 - b_3) \qquad a_1 \geq 0, a_2 \geq 0 \qquad \text{(eq. 10)}$$

c. Multiplication

$$\widetilde{A}(X)\tilde{B} = (a_1, a_2, a_3)\ (X)\ (b_1, b_2, b_3) = (a_1\ X\ b_1, a_2\ X\ b_2, a_3\ X\ b_3) \qquad a_1 \geq 0, a_2 \geq 0 \qquad \text{(eq. 11)}$$

d. Division

$$\tilde{A}(/)\widetilde{B} = (a_1, a_2, a_3)\ (/)\ (b_1, b_2, b_3) = (a_1/b_1, a_2/b_2, a_3/b_3) \qquad a_1 \geq 0, a_2 \geq 0 \qquad \text{(eq. 12)}$$

e. Multiplication of a TFN by a constant (e.g., a weight)

$$k\ (X)\tilde{A} = (\ k\ X\ a_1,\ \ k\ X\ a_2, k\ X\ a_3) \qquad a_1 \geq 0, \mathrm{k} \geq 0 \qquad \text{(eq. 13)}$$

f. Division a TFN by a constant

$$\frac{\tilde{A}}{k} = \left(\frac{a_1}{k}, \frac{a_2}{k}, \frac{a_3}{k}\right) \qquad a_1 \geq 0, a_2 \geq 0 \qquad \text{(eq. 14)}$$

3.3.2.2.2 Steps

When AHP is used to gain weights or the importance level of the subcriteria and also test the consistency level (which TOPSIS does not provide), Fuzzy TOPSIS aims to evaluate the chosen alternatives (i.e., the suitable tenure forms) using a combination of the input from AHP weights and fuzzy assessment. Steps taken for conducting Fuzzy TOPSIS analysis (see Figure 17) are following Chen (2000), Junior et al. (2014), Amiri (2010), Prasongko and Gernowo (2015).

1. Rating the alternatives.
   The alternatives refer to the suitable tenure forms.
   We reviewed the characteristics of the tenure forms and their performance was heuristically evaluated and rated based on their applicability to the secure criteria. The applicability may refer to whether the tenure forms can provide, or support and do not block the landholders to obtain, the respected secure situation. The result of this heuristic evaluation is available in Appendix 4. References for evaluation are the literature, regulations, guidelines, and information gained from field observations, and interviews. Five linguistic variables of performance level were used to show the level of applicability (see Table 18 and Figure 16).

Table 18. Linguistic variables and its fuzzy number

Variable linguistic Level of performance (Class)	Interpretation	Fuzzy numbers
Very Good (VG)	Very applicable/very relevant (the tenure form performs very well concerning the respected situation and on all terms and conditions)	7,5, 10, 10
Good (G)	Applicable/relevant in numerous conditions (the tenure form performs well concerning the respected situation and on a lot of terms and conditions)	5, 7,5 , 10
Fair (F)	Applicable/relevant in specific conditions (the tenure form performs fairly concerning the respected situation and only in specific terms and conditions)	2.5, 5, 7,5
Poor (P)	Less applicable/less relevant (the tenure form performs poorly concerning the respected situation)	0, 2,5, 5
Very Poor (VP)	Inapplicable/irrelevant (the tenure form cannot or almost cannot be implemented to achieve the respected secure situation in the subcriteria)	0, 0, 2,5

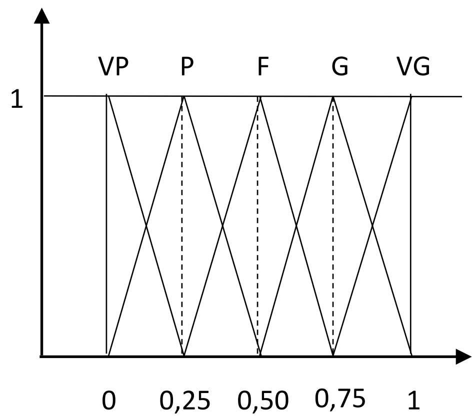


Figure 16. Linguistic values for alternative ratings

The evaluation was put into an evaluation matrix table. Table 19 shows the example of the evaluation for HGB.

Table 19. Example of heuristic evaluation (for HGB)

	A1	A2	A3	A4	B1	B2	B3	C1	C2	…	F2
HGB	F	VG	VP	VG	VG	VG	P	F	VG	…	VG
…	…	…									
SKT											

In the intersection of Row HGB and Column A2, we assigned VG. As the right that indeed gives its holder a full right to use the land for constructing buildings and utilizing them, HGB is very reliable to achieve the secure situation from subcriteria A2 (Convenience to use the land for housing). Hence, the performance of HGB is classified as Very Good (VG).

2. Assemble fuzzy decision matrix $\widetilde{D}$ by assigning the correlated fuzzy numbers for every performance level (Table 19) as had been assigned previously in the evaluation matrix.

   The evaluation result was arranged in matrix *i x j* format. The rows show the suitable tenure forms and the columns represent the subcriteria.

$$\widetilde{D} = \begin{array}{c} \\ A_1 \\ A_2 \\ \vdots \\ A_m \end{array} \begin{array}{c} \begin{array}{cccc} Sc_1 & Sc_2 & Sc_3 & Sc_n \end{array} \\ \begin{bmatrix} x_{11} & x_{12} & x_{13} & x_{1n} \\ \tilde{x}_{21} & \tilde{x}_{22} & \tilde{x}_{23} & \tilde{x}_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ \tilde{x}_{m1} & \tilde{x}_{m2} & \tilde{x}_{m3} & \tilde{x}_{mn} \end{bmatrix} \end{array} \quad \text{(eq. 15)}$$

$A_1 \ldots A_m$ = Alternatif = suitable tenure forms (A_i), i = 1, 2, …m
$Sc_1 \ldots Sc_n$ = Subcriteria (Sc_j), j = 1, 2, …., n
$\tilde{x}_{ij}$ = Evaluation result of the tenure forms applicability against the subcriteria. The result is presented in fuzzy numbers.

Following its level of performance, the intersection of HGB and A2, VG is represented by fuzzy number 7,5 , 10, 10 (Table 20).

Table 20. Fuzzy decision result for HGB

	A1			A2			…			F2		
	a_1	a_2	a3	a_1	a_2	a3	a_1	a_2	a3	a_1	a_2	a3
HGB	2,5	5	7,5	7,5	10	10	..	…	…	7,5	10	10
…	…	…										
SKT												

3. Normalizing fuzzy decision matrix $\widetilde{D}$ using linear scale transformation.
   The normalized fuzzy decision matrix $\widetilde{R}$ is given by

$$\tilde{R}=[\tilde{r}_{ij}]_{mxn} \quad \text{(eq. 16)}$$

   The normalized fuzzy value ($\tilde{r}_{ij}$) is gained by dividing the value of each fuzzy number with the maximum value.

$$\tilde{r}_{ij} = \left(\frac{a1_{ij}}{a3_j^*}, \frac{a2_{ij}}{a3_j^*}, \frac{a3_{ij}}{a3_j^*}\right), a3_j^* = max_i a3_{ij} \quad \text{(eq.17)}$$

4. Compute the weighted normalized decision matrix, $\widetilde{V}$, by multiplying the weights of the evaluation criteria, $\widetilde{W}_j$, by the elements $\tilde{r}_{ij}$ of the normalized fuzzy decision matrix.

$$\widetilde{W}_j = \text{the weights given by AHP analysis of j}_{\text{th}} \text{ subcriteria} \quad \text{(eq. 18)}$$

$$\tilde{V} = [\tilde{v}_{ij}]_{mxn} \quad \text{(eq. 19)}$$

And $\tilde{v}_{ij}$ is given by

$$\tilde{v}_{ij} = \tilde{x}_{ij} x \, \widetilde{w}_j \quad \text{(eq. 20)}$$

5. Define the Fuzzy Positive Ideal Solution (FPIS, A^+) and the Fuzzy Negative Ideal Solution (FNIS, A^-).
An FPIS is composed of the best performance values for each alternative whereas the FNIS consists of the worst performance values.
According to Chen (2000), Amiri (2010), and Junior et al., (2014) FPIS and FNIS are determined as

$$A^+ = \{\tilde{v}_1^+, \tilde{v}_j^+, \ldots, \tilde{v}_m^+\} \quad \text{(eq. 21)}$$

$$A^- = \{\tilde{v}_1^-, \tilde{v}_j^-, \ldots, \tilde{v}_m^-\} \quad \text{(eq. 22)}$$

Where $\tilde{v}_j^+ = (1,1,1)$ and $\tilde{v}_j^- = (0,0,0)$

6. Compute the distances d_j^+ and d_j^- of each alternative from v_j^+ and v_j^-, respectively.

$$d_j^+ = \sum_{j=1}^{n} d_v (\tilde{v}_{ij}, \tilde{v}_j^+) \quad \text{(eq. 23)}$$

$$d_j^- = \sum_{j=1}^{n} d_v (\tilde{v}_{ij}, \tilde{v}_j^-) \quad \text{(eq. 24)}$$

Where *d*(.,.) represents the distance between two fuzzy numbers. The vertex method to calculate the distance between $\tilde{A}$ and $\tilde{B}$

$$d(\tilde{A}, \tilde{B}) = \sqrt{\frac{1}{3}[(a_1 - b_1)^2 + (a_2 - b_2)^2 + (a_3 - b_3)^2]} \quad \text{(eq. 25)}$$

7. Compute the Closeness Coefficient, CC_i.
The closeness coefficient CC_i represents the distances to the FPIS and FNIS, simultaneously

$$CC_i = \frac{d_i^-}{d_i^+ + d_i^-} \quad \text{(eq. 26)}$$

8. Define the alternatives ranking from the CC_i. The higher the CC_i the higher the rank. The best alternative is closest to the A^+ and farthest to the A^-.

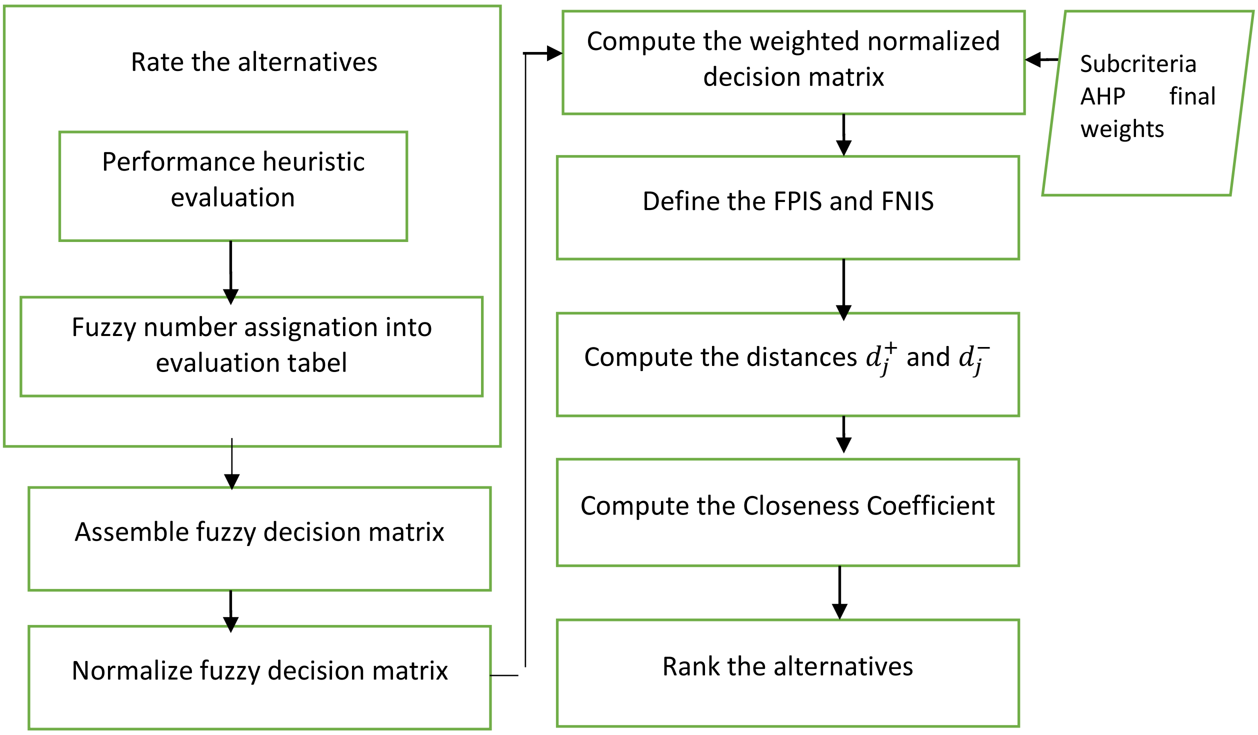


Figure 17. Fuzzy TOPSIS analysis flowchart

3.3.2.2.3 Results: optimum tenure forms

The produced fuzzy decision matrix, normalized decision matrix, weighted normalized decision matrix, and FPIS/FNIS can be seen in Appendix 5.

The calculation results for d_j^+, d_j^-, and CCi, for each alternative are as follows.

Table 21. Fuzzy TOPSIS results

No	Alternatives (tenure forms)	d_j^+	d_j^-	CCi	Ranking
1	HP	17,856707	0,1451453	0,0080628	1
2	HGB	17,872026	0,131764	0,0073187	2
3	SKT	17,874832	0,1287555	0,0071517	3
4	HK	17,876013	0,1273686	0,0070747	4
5	NB system	17,89956	0,1055574	0,0058626	5
6	SWK	17,918297	0,0882416	0,0049005	6
7	IL/IP	17,919885	0,0866666	0,0048131	7
8	ST	17,924483	0,083459	0,0046346	8
9	SPI	17,926207	0,0810159	0,0044991	9
10	SWBT system	17,938631	0,068973	0,0038302	10
11	GR	17,951137	0,0579281	0,0032166	11

3.3.3 Tenure conformity

In this research, the term tenure conformity is defined as a concept to show the aptness of rights assignation (“pemberian hak”) for statutory tenure forms, or tenure avowal (“pengakuan hak”) and tenure affirmation (“penegasan hak”) for non-statutory tenure forms towards some placement criteria. Using the findings from Puslitbang BPN (2010) about the best practice of land management in Indonesian coastal areas, this study uses a heuristic approach for doing the tenure placement analysis. The analysis considers that the location of the parcels, or also called geographical knowledge (Tong, Muray, and Xiao, 2009), will determine which correct tenure forms will or can be assigned to the parcels based on some regulatory principles and practical rules. In this study, the conformity is made to spatial plans and the physical setting of the parcels.

3.3.3.1 Geographical setting

To get an understanding of the geographical setting of tenure arrangement, this thesis first investigates the spatial boundary of tenure placement. As the landward boundary of tenure arrangement is high tide shoreline and the focus of the study area is just in the coastal waters/aquatic lands (not in "normal lands" or land parts of the coastal area), the boundary that needs to be clarified is the one extending seaward. In a questioning statement, the matter can be raised as:

How far the statutory tenure forms can be assigned extending seaward and the coastal customary tenure forms can be acknowledged in the coastal waters?

One approach to address that question is by looking into definitions. A coastal area is commonly agreed upon as the interface between land and sea, defined as the part of the land affected by its proximity to the sea/influence of marine processes, and the part of the sea affected by its proximity to the land/influence of terrestrial processes (Balasuriya, 2018). In line to that definition, Dahuri and Rais (2004) states the coastal zone's boundary is ecologically generated by those influences. Its land part is determined by the farthest influence of the characteristics of the sea, such as tides, sea breeze, and permeation of salt water, whereas its sea part is by natural processes that occur on land such as sedimentation, freshwater flows, and by the processes caused by human activities on land such as deforestation and pollution.

For the purpose of regional planning and management, the boundary is usually pragmatically and spatially determined. In principle, the seaward boundary can be determined parallel to the coastline (horizontal/longshore) or perpendicular to the coastline (vertical/cross-shore).

According to Vallega (1999), the boundary can be set arbitrarily (based on the baseline), physically (from the mean high tide or low tide), or legally and administratively (based on the boundary of administrative areas and legal rules). Depending on the physical and environmental, social, economic, cultural, and governance systems, the boundary might vary among regions and countries.

Table 22 shows the variation of the approach, type, and the distance of the seaward boundary. China and the UN Millennium Assessment, for example, adopt the cross-shore principle with specified limits of 15 m and 50 m, respectively. Sri Lanka adopts the longshore principle with a physical benchmark up to 2 km from the mean high tide line. California State is using an administrative and jurisdictional approach.

In Indonesia, the seaward boundary of the coastal area is the longshore type. The boundary is approached by the combined juridical and administrative with the arbitrary measurement. The coastal waters are defined as territorial sea waters that connect beaches and islands, estuaries, bays, shallow waters, brackish swamps, lagoons, and other related areas. The Law No. 32 of 2004 jo. Law Number 23 of 2014 concerning Regional Government states that the territorial sea has a seaward boundary of 12 nautical miles (22,227 kilometers) from the coastal baseline.

Table 22. Coastal zone seaward boundary in several places

No	Coastal zone boundaries Seaward	Area, Country	Source
1	12 km from high tide level	Brazil	Sorensen and Mc. Creary (1990:10) in Dahuri and Rais (2004)
2	Low tide level	Costa Rica	
3	Until the depth of 15 m	China	
4	12 nautical miles from high tide level	Spain	
5	2 km from mean high tide line	Srilanka	
6	The state's outer limit of jurisdiction, including all offshore islands	California State, the US	California Coastal Act 1976, from California Coastal Commission (2018)
7	3 nautical miles the territorial sea baseline.	Queensland, Australia	*Coastal Waters (State Title) Act 1980,* from Department of Environment and Science, Queensland Government (2015)
	The baseline may be represented by following the low water mark or by following gazetted 'straight' lines—which are straight baselines, river closing lines and bay closing lines		
8	50 m below mean sea level		United Nations Millennium Assessment, as in Department of Environment, Land, Water and Planning (2016)

However, Minister of ATR/Head of BPN Regulation No. 17 of 2006 on the Land Management in Coastal Areas and Small Islands Article 4 states that for regional land management activities, the seaward boundary of coastal water management should follow the sea jurisdiction of the province, extending up to a distance equal to the territorial sea jurisdiction and coastal spatial planning operating area. Therefore, it can be concluded that in Indonesia, the seaward boundary of decentralized coastal area management should follow the sea jurisdiction of the province where the land is located, with the farthest distance being 12 nautical miles (see Figure 18). After 12 nautical miles, the jurisdiction of management belongs to the central government.

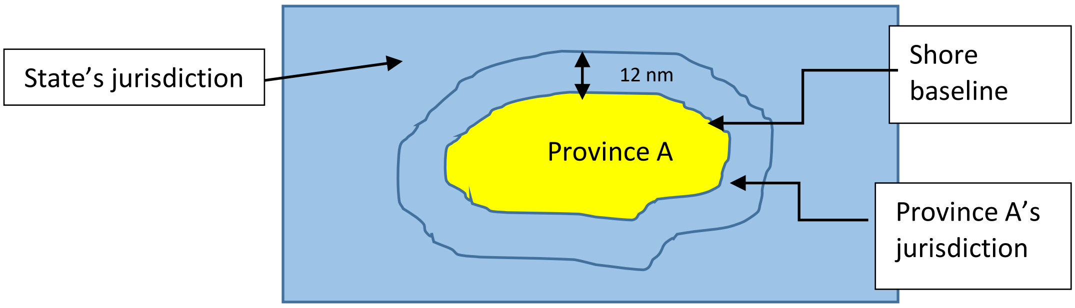


Figure 18. Jurisdiction of provincial waters

Between two provinces bordering the sea, according to Minister of Internal Affairs Regulation No. 76 of 2002 concerning Regional Boundary Delimitation Guideline, if the straight distance between them is more than 2 x 12 = 24 nautical miles, the boundary between two adjacent provinces is measured from the baseline of the high tide shoreline until the median line of the distance (Figure 19).

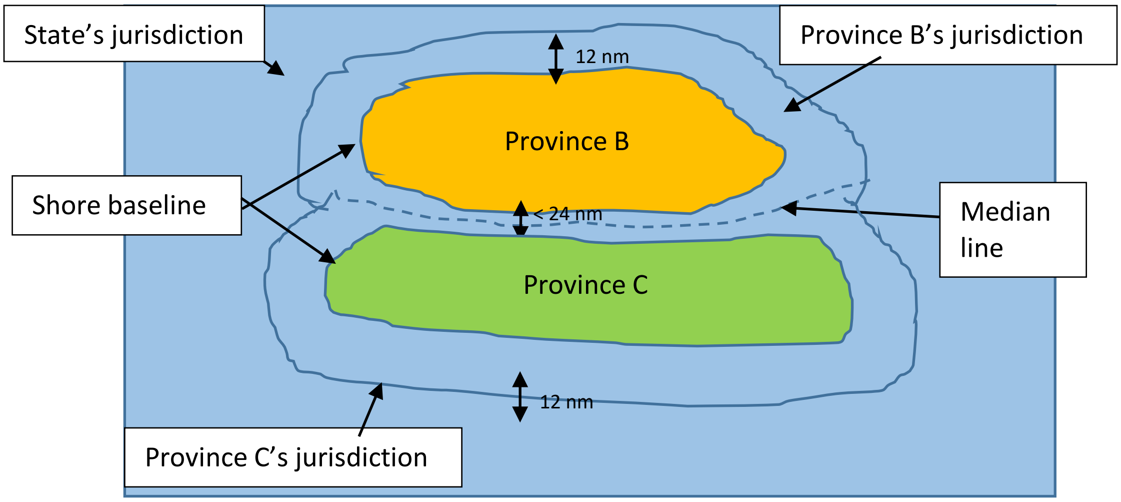


Figure 19. Waters jurisdiction of two adjacent provinces

Tenure placement boundary for the living house

When tenure arrangements can take place within the province's jurisdiction with a maximum of 12 nautical miles, is the tenure placement boundary for the living house belonging to coastal communities also following the same distance? It is important to note that the object of this elaboration is house buildings and is not the specific sea buildings, such as oil and gas rigs and platforms.

This thesis has identified that there are some insights to determine the seaward boundary of housing occupation in the coastal waters:

1. Local practice.
   From this view, the farthest boundary is the outermost side of the area where the coastal communities are still able to build their houses according to their own consensus regarding spatial arrangements. This argument is referring to the pragmatic view of Harsono (2008) and Sofyan (2016) who denote that as long as the buildings established by the locals are connected physically to the mainland (by road, for example), the area where the building stands can be treated as built-up area, similar to the usual a built-up area in the hinterland. The property

there is also assumed to be eligible to be given any permitted land rights. Another underlying thought is that the way the locals arrange the settlement and define its boundary reflects their knowledge of choosing and managing the territorial waters as a place to live and earn a livelihood. The locals normally build their houses in an area where strong waves and wind are minimal and will not affect the breeding area, catchment zone, or channel for boat transportation. In Penyengat Island waters, for example, which is known as the suitable area for "siput gonggong" or sea slug *strombus canarium* (Putra et al., 2014), the locals allocate vacant areas that are intentionally for the purpose of *siput gonggong* breeding and catchment area and hence limit the housing occupation in the area (Figure 20).

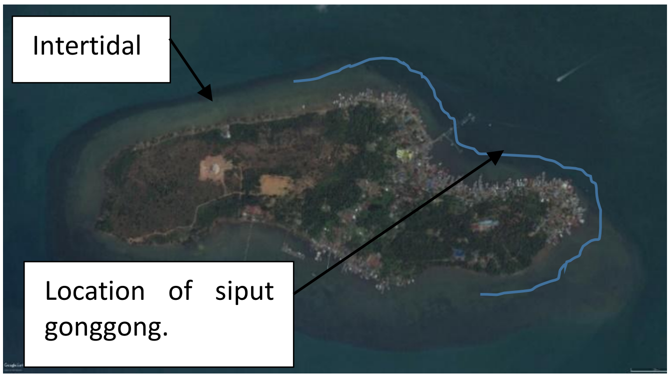


Figure 20. Penyengat Island and the area for *siput gonggong*

Figure 21. *Karamba Jaring Apung* in Madong area.

In Madong and Tanjung Sebaok, because the waters around the settlement are suitable for placing the "karamba jaring apung" (see Figure 21) or floating net for fish breeding for *kerapu macan* fish/*Epinephelus fuscoguttatus* (Afrizal, Zen, and Raza'I, 2016), the locals also limit the house expansion extending seaward (personal interview with Pak Marwan, Head of Madong Village, 26 November 2016). Our simple investigation using satellite imagery of several shore settlements in the study area reveals that the distance, which is measured perpendicular from the line separating sea and land towards the outermost house, of the housing occupation various in length among the shore settlements.

Table 23. Seaward distance of the settlements

No	Location of the settlement	Approximate longest distance (m)
1	Tanjungpinang Kota	460
2	Kamboja	810
3	Tanjung Unggat	251
4	Senggarang	455
5	Kampung Bugis	451
6	Teluk Keriting	160
7	Kampung Bulang	58
8	Tanjung Sebaok	83
9	Madong	79
10	Penyengat Island	88
11	Dompak Darat	52
12	Klam Pagi	38
13	Dendun Island	132

Table 23 shows that each settlement exhibits varying distances of seaward housing. This distance reflects the extent of land occupied by housing: the greater the distance, the larger the residential area extending towards the sea. The settlements in Tanjungpinang Kota and Kamboja, the two most urbanized settlements, are much larger than the ones in Dompak or Klam Pagi, which is located in rural areas.

2. Intertidal zone boundary.
   The second option is using the seaward boundary of the intertidal zone, which is generally defined as the area between the highest water level (HWL) and the lowest water level (LWL). This means that the outermost seaward boundary where people are still able to build their houses is marked by the LWL line. Along with the Mean Sea Level (MSL) shoreline, these water level lines are commonly used as references for determining the coastline in topographic maps (i.e., LWL is used in Indonesian Coastal Environment Maps/*Peta LPI*). According to Presidential Regulation No. 51 of 2016 on Coastal Boundary (Sempadan Pantai), the area between the highest and lowest water levels is referred to as the foreshore. In the Indonesian context, the foreshore is essentially equivalent to the intertidal zone. This zone is dynamic, with its width and depth varying depending on the beach's slope, the seafloor gradient, and tidal influences (Nybakken, 1992). In Malang Rapat Village, Bintan Island, for example, the depth of the intertidal zone varies from 0 to 3,4 meters (Simanjuntak et al., 2016), with five classes of inundation duration, that is, around 8,4 days, 51,9 days, 133,9 days, 252 days, and 356 days (almost all year-round). Basith (2014) states that one can determine the intertidal zone by combining tidal data with hydrographic surveys to acquire bathymetric data. The survey would be terrestrial measurements using Total Station or GPS, Jestsky Batrimetric Survey, Unmanned Surface Vessels (USV), Lidar, Synthetic Aperture Radar (SAR), Camera Monitoring System, and from satellite imagery interpretation. In Indonesia, the bathymetric data showing the intertidal zone has been displayed in the base map for the coastal area created by the Geospatial Information Agency (BIG), in Peta LPI. However, for Riau Island area, the LPI map scale is currently available on a regional scale of 1:250.000 and 1:50.000 which can be said to be still general to describe intertidal zones in at least subdistrict-based mapping units and thus, the map should be updated with larger scales. As the alternative for Peta LPI is Indonesian Marine Map (*Peta Laut Indonesia*) from Hydro-Oceanographic Center of the Indonesian Navy, which could be accessed in various scales depending on its availability.

3. Interpretation of regulatory statement.

a. According to Article 18 Point 5 of the Minister of Fisheries and Marine Affairs Regulation No. 23 of 2016 concerning Management Planning of Coastal and Small Islands, one of the priorities for the allotment of coastal waters within seaward distances of 2 nautical miles is for “living space and access for small fishermen, traditional fishermen, small fish breeders, and small salt farmers”. The term “living space” here can mean as a residential place. From this regulation, we notice that the seaward distance of 2 nautical miles (3,704 km) is by stipulation permitted to be a benchmark for building houses.

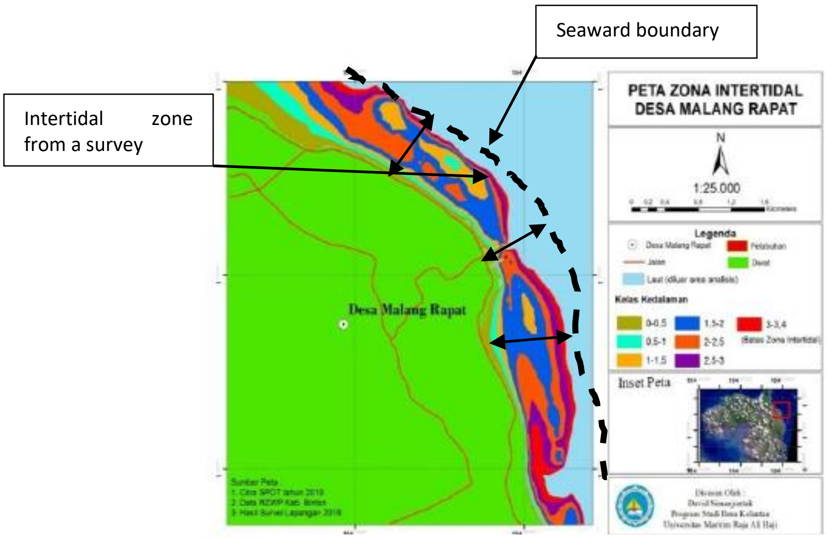
b. Coastal areas and small islands are governed by Regulation No. 17 of 2016 from the Minister of ATR and the Head of BPN. Article 5 of this regulation stipulates that only housing occupations in the coastal waters belong to the indigenous law community (Indonesian: masyarakat hukum adat) and can be recognized by the government. On the shore (Indonesian: pantai), besides the indigenous law community, the recognition could also apply to the housing occupation by the local community that has already inhabited there for generations. Instead of clearly stipulating the benchmark of seaward distance, this regulation just denotes the permitted location of housing occupations that are on the shore and coastal waters within the jurisdiction of the province.

4. Previous research.
Sofyan (2016) proposes 0,5 nautical miles (0,926 km) and 10 meters deep as a subjective benchmark of the horizontal and vertical seaward boundary of the housing occupation in the coastal area. He argues that the benchmark is a reasonable measure to protect marine biota and prevent the trespassing of shipping lines.

Although this thesis argues that regulatory views should be the most important consideration when determining the seaward boundary of housing occupation, it does not strictly adhere to one particular approach. Instead, this thesis attempts to utilize any relevant considerations from different perspectives.

Hence, this thesis proposes that the tenure of housing occupation is following the scheme as follows:

1. The tenure placement for housing occupation should differentiate the subject of housing tenure, which is the indigenous law community and the local community that has resided in the area for generations.
2. Both communities have entitled the rights to build houses on shores. The shore boundary will follow the boundary of the intertidal zone. However, for practicality, we should combine the use of an intertidal zone as a basis for determining the seaward boundary with a horizontal numerical benchmark. This thesis proposes that instead of using the zone depth, it is more applied to use the longest horizontal distance of the intertidal zone as the benchmark of the seaward boundary (see Figure 22). In the discussion with the locals in the study area, it is easier for them to notice the boundary that is measured by the fixed horizontal distance rather than the boundary that has no fixed horizontal distance. As an illustration, if the longest horizontal distance of the intertidal zone from the shoreline is 1.000 m, the distance of the seaward boundary for the whole area is also 1.000 m.
3. Only the indigeneous law community is entitled to build houses in the coastal waters outside the shore. This thesis proposes the distance of the seaward boundary of their housing occupation is 2 nautical miles from the shoreline.
4. If the indigenous law community and local community have their own rule of housing arrangement within the intertidal zone and 2 nautical miles, the seaward boundary is established according to their arrangement. The local housing arrangement is considered void if it crosses the 2 nautical miles benchmark.



(Source of map: Simanjuntak et al., 2016)

Figure 22. Illustration of proposed seaward boundary using intertidal line.

5. The housing arrangement has to follow the rules set by the Spatial Planning (for example, shipping lines, marine conservation areas, sempadan pantai) or another rule made by the local government (for example, a road that was built on purpose to stop the housing from growing out to sea; see Figure 23). This is true within the intertidal zone and 2 nautical miles away.

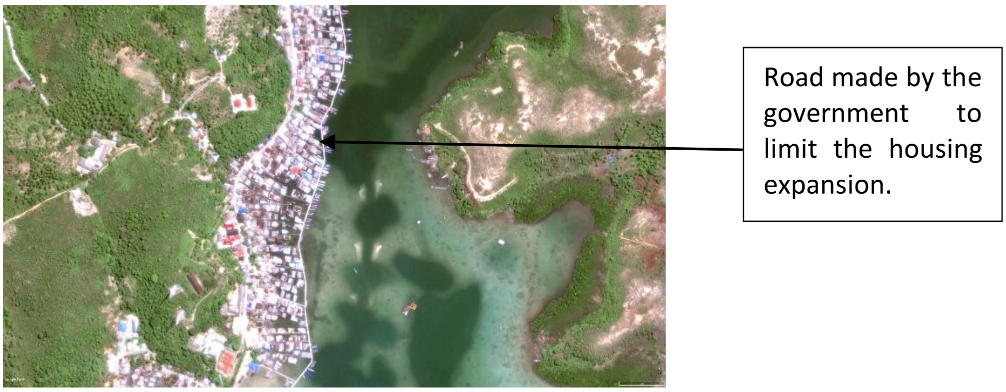
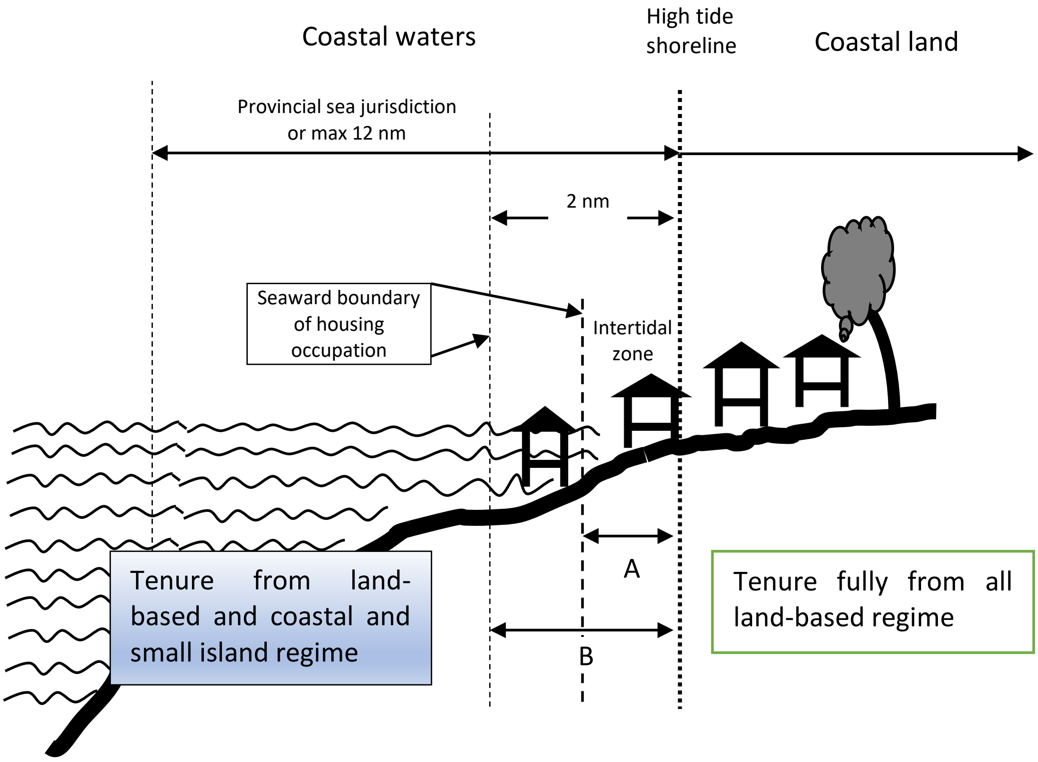


Figure 23. Road as seaward boundary in the settlement in Tambelan Besar Island

The following Figure 24 illustrates the housing occupation arrangement in a horizontal profile.



A. Permitted seaward area for local community that has resided for generations
B. Permitted seaward area for indigeneous law community

Figure 24. Permitted seaward area for housing in coastal areas

3.3.3.2 Conformity to the spatial plan

Law No. 26 of 2007 on Spatial Planning defines spatial plans as the establishment of the spatial structure and pattern. Space structure, or spatial structure, is an arrangement of settlement centers and the network of facilities and infrastructure that functions to support the social and economic activities of a society. The spatial pattern, or land use plan, is the distribution of spatial allotment, which shows the zones of any forms of cultivation/built-up areas and conservation/protected areas. Specifically, the conformity assessment of tenure forms in this thesis examines their adherence to spatial allotment across all stipulated zones, extending beyond merely checking the conformity within settlement or housing zones.

The conformity is ruled in Government Regulation No. 16 of 2004 concerning Land Management (Explanation Part of Article 9 point 2)

> *"Pemanfaatan ruang…, tidak mempengaruhi hubungan hukum atas tanah dengan syarat penggunaan dan pemanfaatannya sesuai dengan Rencana Tata Ruang Wilayah dan tidak mengganggu pemanfaatan ruang di atas dan atau di bawahnya"*

[Space-utilization..., does not affect the legal relationship to land with the condition that the use and the utilization conform to the Spatial Plan and do not interfere the use and utilization of the space above and below it]

Directorate of Marine, Coastal, and Small Islands Spatial Planning (2013) defines a zone as the space in which its usage has been mutually agreed upon by various stakeholders and its legal status has been determined. It can be said that the allotment in the zones is essentially a legalized reflection of a compromise between the existing land use with the private demand and public needs in the nexus of economic demand, ecosystem protection, and the social and cultural setting (Wahid, 2014). As a consequence, each zonation has regulative power to permit or forbid the kind of usage and utilization brought by land rights to occur. In case the unconformity occurs, according to Articles 20 and 23 of Government Regulation No. 16 of 2004 concerning Land Management, the rights can end and be released to other parties.

> *"Penguasaan, penggunaan, dan pemanfaatan tanah yang tidak sesuai dengan Rencana Tata Ruang wilayah disesuaikan melalui penyelenggaraan penatagunaan tanah"*
> [Land tenure, use, and utilization that are not in line with the RTRW will be adjusted through land management/stewardship].

Article 23 that stipulates the type of the adjustment, in Point 3 denotes that one of the adjustment is

> *"Penyerahan dan pelepasan hak atas tanah kepada negara atau pihak lain dengan penggantian sesuai dengan peraturan perundang-undangan"*
>
> [Submission and release of land rights to the state or other parties with replacement in accordance with the laws and regulations]

To some degree, the spatial plans can also show the status of the area, whether it belongs to free state land (e.g., settlement zones), non-free state land (e.g., conservation zones), or "adat" land (e.g., traditional villages that have been designated as world heritage areas). Sutaryono (2016) states that the agreement between assigning rights (in the case of statutory tenure forms) and the spatial plan is an example of how land registration, which handles property rights, and land use planning, which handles development rights (the right to use the land for different types of development interests), are becoming more in sync with each other. Adrianto (2012) said that property rights relate to structural rights, while development rights are connected to functional rights (rights that reflect land use and land utilization following the functions).

In the Indonesian context, as we already noticed, the property rights take the form of land rights as stipulated by BAL. The functional rights in coastal areas, on the other hand, are governed by Law No. 26 of 2007 concerning Spatial Planning as a representation of land regime and Law No. 27 of 2007 in conjunction with Law No. 1 of 2014 concerning Coastal Areas and Small Islands as a representation of marine coastal regime. Zoning in land-based regime spatial plan is called the Spatial Plan (RTRW), and in the marine coastal regime called Zonation Plan (RZWP3K). Different from structural rights that have the titled forms, functional rights are embedded in the zonation itself and typically do not have any format or only in the form of permits for some functions. The conformity to the spatial plans should take both RTRW and RZWP3K because they are overlapped in the coastal area (Figure 25).

In the law about spatial planning that stipulates RTRW:

> *Ruang daratan adalah adalah ruang yang terletak di atas dan di bawah permukaan daratan, termasuk permukaan perairan darat dan sisi darat dari garis laut terendah. Ruang Lautan adalah ruang yang terletak di atas dan di bawah permukaan laut dimulai dari sisi*

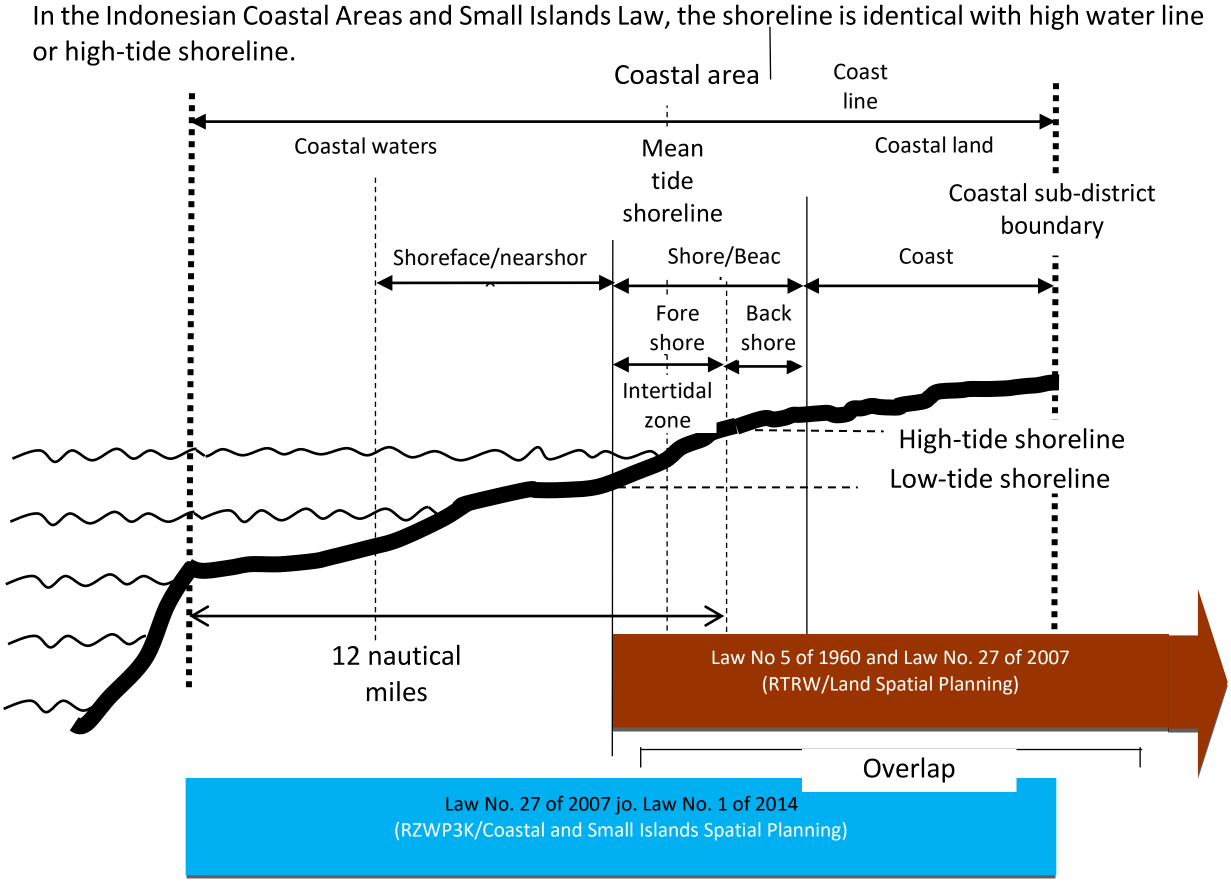
laut dari sisi garis laut terendah termasuk dasar laut dan bagian bumi dibawahnya, dimana negara Indonesia memiliki hak yuridiksinya.

[Land space is a space on and below land, including the floor of inland waters and land-side from the lowest waterline. Sea space is a space located on and below the sea, starting from the sea side from the lowest waterline, including the seabed and the earth below, where Indonesia has its jurisdiction]
(Law No. 26 of 2007 on Spatial Planning, Article 1)

Whereas in the law about coastal and small islands that stipulates RZWP3K, it is written that

Undang-Undang ini diberlakukan di Wilayah Pesisir dan Pulau-Pulau Kecil yang meliputi daerah pertemuan antara pengaruh perairan dan daratan, ke arah daratan mencakup wilayah administrasi kecamatan dan ke arah perairan laut sejauh 12 (dua belas) mil laut diukur dari garis pantai ke arah laut lepas dan/atau ke arah perairan kepulauan. [This law applies in the coastal areas and small islands, which cover the meeting area between the influence of the waters and the land, where on the land encompasses the administrative area of the sub-district and seaward extending as far as 12 (twelve) nautical miles measured from the shoreline to the open sea and/or towards the islands waters]

In the Indonesian Coastal Areas and Small Islands Law, the shoreline is identical with high water line or high-tide shoreline.



The zone division of the coastal is adapted from CERC (1984).

Figure 25. The operational area of the RTRW and RZWP3K in the coastal areas.

The hierarchical structure of RTRW and RZWP3K are presented as below:

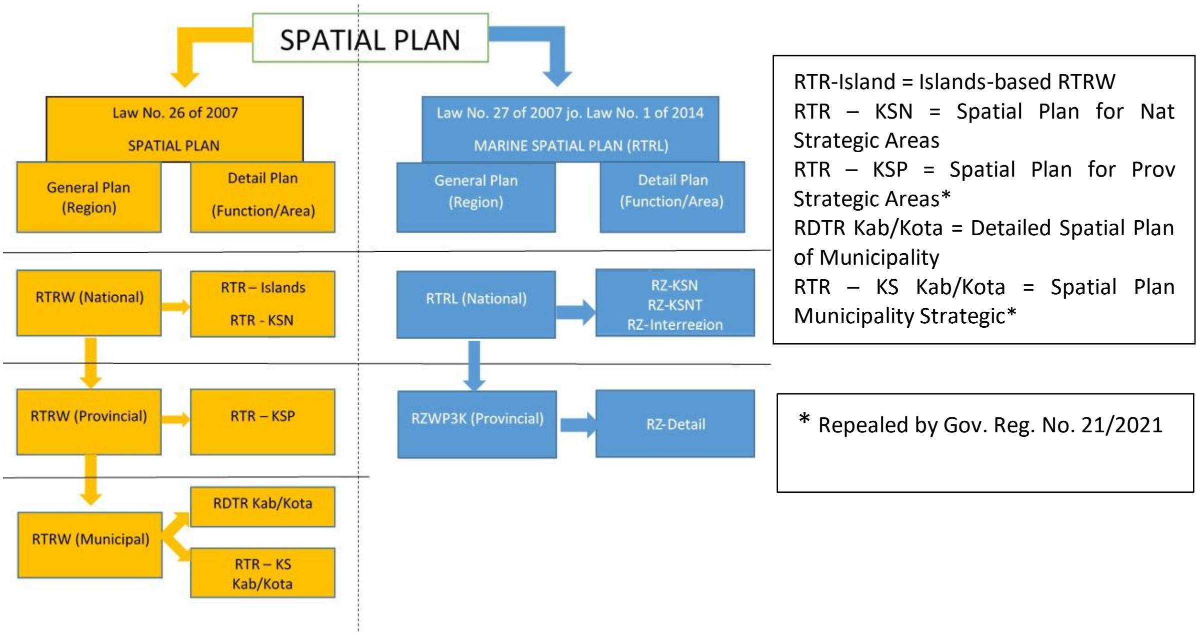


Figure 26. Spatial planning hierarchy

Figure 26 shows the authority of planning is distributed and differentiated based on administration governance and the functional level. Under land-based regulation in Law No. 26 of 2007 on Spatial Planning, the administration governance is made following the structure of Indonesian government, from national (*Pusat*), provincial (*Daerah Tingkat I*), and municipality level (*Daerah Tingkat II*). The planning based on the functional level can be divided into island and national strategic areas (national level), provincial strategic areas (provincial level), and municipal strategic areas and detailed plans (municipal level). Under Coastal and Small Island Laws (Law No. 29 of 2007 jo. Law No. 29 of 2007 and Law No. 1 of 2014, also known as the Coastal and Small Island Laws, only allow administration-based governance at the national and provincial levels. This is because Law No. 23 of 2014 on Regional Government gives the municipality power to manage its marine area at the provincial level. It means, while the RTRW is detailed at the municipality level, the RZWP3K is only taking its most detailed level in the provincial tier. In the coastal and small islands spatial planning, the arrangement based on the area functionality is divided into strategic areas at the national and provincial level and also at the interregional level. The interregional planning aims to govern marine geographical features spatially that span across provincial borders, such as bays and straits.

Both RTRW and RZWP3K consist of two main allotment zonations: cultivation/built-up areas/general usage areas and protected/conservation areas. As in the Minister of Marine and Fisheries Regulation No. 28 of 2021 on Marine Spatial Planning Management, in RZWP3K the government adds two other areas, namely national strategic areas and sea lines (alur laut). The tenure forms from the previous analysis are intended to the occupation around coastline settlement areas. The settlement, which consists of houses, network utilities, facilities, infrastructure, and other supporting environments for livelihood, living, and working of the people, is normally located in the built-up areas. So, for assessing the conformity of a piece of land in a coastline settlement to the tenure forms from previous analysis, we focus on the stipulated zones inside the built-up areas of both RTRW and RZWP3K. However, there is some situation when in the other zones (the protected areas/conservation areas, national strategic areas, and sea lines), people activities in using aquatic land exist, including for residential activities, and are allowed by the regulations, which shows that in those zones land occupation is also occurring. To those zones, we still determine the conformity of the tenure forms, with an explicit notification that if the zones are not relevant (e.g., not possible in the coastal areas, for example), they are excluded. In doing the conformity check, we were guided by questions.

In coastal areas:

1. Could we assign statutory land tenure forms in this zone?
2. Regarding non-statutory tenure forms: “in this zone, could the tenure be kept by the landholder?”

3.3.3.2.1 Tenure conformity to RTRW

RTRW Kab/Kota is stipulated by the municipal government for a validity of 20 years with a possibility for revision every five years. In Tanjungpinang City, the spatial plan is established with Tanjungpinang City Regulation No. 10 of 2014 concerning Regional Spatial Planning of 2014-2034, revised by Tanjungpinang City Regulation No. 11 of 2024 concerning Regional Spatial Planning of 2024-2044. In Article 3 of the revised regulation, the RTRW has the function as:

a. Reference for Regional Long Term Development Plan (RPJPD) and the Regional Medium Term Development Plan (RPJMD) establishment.
b. Reference for space utilization/urban development.
c. Reference for realizing equitable development.
d. Reference for the investment by the government, people, and private sectors.
e. Reference for Detailed Spatial Plan.
f. The basis for any control mechanism of land use in urban areas, which includes the establishment of zoning regulations, licensing, the issuance of incentives and disincentives, and the imposition of sanction.
g. Reference for land administration.

As the reference for land administration as shown by point g, the RTRW broadly divides the arrangement of tenure and allotment into built-up/cultivation areas and protected/conservation areas. Both areas then are categorized again into several smaller zones. The categorization is dependent on the development policy of the municipality itself, meaning the zones stipulated by Tanjungpinang City Government would be different from the ones established by other municipalities. To some irrelevant zones of land use plan, we did not assess the placement conformity. To establish the conformity between the suitable tenure forms and the RTRW zones, we used some regulatory-based perspectives. Following Putri and Sesung (2018), a systematic interpretation technique is utilized in the analysis, involving a review of interrelated articles within a given regulation, as well as connections to provisions in other pertinent legislation, to gain clarity. Several main points of the assessment are presented in the following statements.

1. The implementation of Spatial Plans do not nullify the legitimacy of human-land relationship (Article 9, Government Regulation No. 16 of 2004 on Land Use Management).
   That principle provides the consequence that:
   a. Non-statutory and customary land tenure can exist in the zones on the condition that the use of land is similar with the permission use embedded in the stipulated zones.
   b. Statutory land tenure can only be assigned to a piece of land in a zone if there are supporting rules and the use of land does not contravene the restrictions embedded in the stipulated zones.
2. A designation of a zone does not inherently restrict the activities permitted within it. For instance, a commercial and service zone does not exclusively permit commercial activities. Other uses, such as housing, may also be allowed, provided they are stipulated in the zoning regulations. Consequently, more than one tenure form may be applicable within a single zone.

For example, Article 22 of Perda RTRW Tanjungpinang stipulates that activities such as offices, small industries, vertical housing, public transportation, and utility facilities—all of which involve occupying land and need certain tenure—are still allowed.

3. The state through government bodies can have legal relationships similar to those of private individuals with their possessions. The legal relationship between the state and land falls under the category of public property (or *res publicae*): land used for public purposes. Land for general public services, such as government office buildings, is considered *res publicae in publico usu* (public things in public use) and thus becomes state property. Using this concept, for a public property such as roads, government bodies can be assigned a formal land right, which is in the form of HP.
4. In principle, lands in the protected areas without any prior right could be granted land rights, except in (protected) forest areas (Article 11 Paragraph 1, Government Regulation No. 16 of 2004 on Land Use Management).

a. In the foreshore, the land with buildings functioning for security and defense, harbors or jetties, beach towers, and houses belonging to indigenous communities or local communities that have resided in the area for generations could be given the land-based statutory tenure forms from BAL (Article 5 of Minister of ATR/Head of BPN Regulation No. 17 of 2016 on Land Management in Coastal Areas and Small Islands). HP can be assigned to the government usage on a piece of state land regardless of the zonation, except there is a regulation that says otherwise, whereas HGB can only be given in the built-up areas. Both HGB and HP are relevant for any service and commercial land use (e.g., resorts, hotels, restaurants, and shop houses). KKPR, formerly known and stated in this thesis as IL/IP, is required for acquiring formal land rights from BAL (Permen ATR/Head of BPN No. 18 of 202, Article 197). Permen KP No. 28 of 2021 states that this is a document required for any activity involving the utilization of marine waters and its jurisdictional areas.

Furthermore, Article 113 Paragraph 1 of this regulation explains that any person conducting fixed utilization activities (>30 days) in coastal waters, territorial waters, and/or jurisdictional areas in a part of the marine space is required to have a KKPR Laut. The jurisdictional area includes the sea surface, water column, and/or seabed (Article 113 Paragraph 2).

5. According to Law No. 41 of 1999 on Forestry (Articles 6, 8, and 9), based on its function, forest areas can be divided into protected forests/conservation forests, production forests, special purpose forests, and urban forests. The tenure that applies in protected/conservation forests is state tenure, which means that only the state can hold the tenure for the use of environmental protection and nature conservation.
6. According to Article 11 point 2 of the Government Regulation No. 16 of 2004 on Land Use Management, principally, the parcels on cultural heritage areas without any prior rights can be granted rights in accordance with prevailing laws and regulations, except for the very location of the site. In Article 73 of Perda RTRW Tanjungpinang, the activities can only be allowed if they do not risk the existence of the site or cause any harm to the site.
7. Minister of Transportation Regulation No. 68 of 2011 concerning Sea Shipping Line regulates that shipping lines and public ports are only for transportation purposes and necessarily clear to any other occupation and usage. In this context, to those areas, the tenure that applies should be the state tenure. It can be said that those lands are state-owned lands.
8. Open green areas (RTH) are defined as open, elongated, clustered, or lane areas intended for vegetation growth and nature recreational activities. Article 7 of Perda RTRW Tanjungpinang mentions that the RTH can be divided into Public and Private RTH. Public RTHs are located mostly on public or state land. Examples of Public RTH are the green lane along the roads, city parks, green lane along the beach, and urban forest. Private RTH is the land inside residential areas whose function is specified by the government as green areas. On the Public RTH, the government could only assign HP as the proper land right. On the Private RTH, any eligible tenure forms are permitted.

9. According to Article 10 of Perda RTRW Tanjungpinang, *sempadan pantai* zone, which is generally located on backshore, is allowed to be occupied and used strictly only for utility buildings and specific natural tourism activities (tourism beach run by the state-owned company, for instance). Any activity that will change its function as a protected area is forbidden. This stipulation makes only HP for governmental bodies that is eligible.
10. Article 25 of Perda RTRW Tanjungpinang about defense and security area stipulates that only the defense and security infrastructure and activities are allowed in the zone. As a result, only HP for governmental bodies applies.
11. In case the RTRW and RZWP3K stipulate the cleared zone for disaster mitigation, according to Law No. 24 of 2007 concerning Disaster Management Article 32, the government has the authority to set those areas as the forbidden areas for settlements, relocate the people in case they are already there, and hence revoke the tenure of the occupants on the lands.

The results of the assessment can be seen in Table 24 and Figure 27.

Table 24. Conformity check of tenure forms with zonation in RTRW

Functions	Allotment zones/Land use plan	Tenure forms										
		HP	HGB	SKT	HK	NB	SWK	IL/IP	ST	SPI	SWBT	GR
Kawasan Budidaya (Built-up/cultivation areas)												
1. Road		✓*						✓				
2. Production forest areas	Permanent production forest areas											
	Convertible production forest areas											
3. Agriculture areas	Horticulture areas			✓					✓		✓	✓
4. Tourism areas		✓	✓	✓	✓			✓				
5. Industrial areas		✓	✓	✓			✓	✓				
6. Residential areas	Housing areas	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓
	Public facilities and social facilities areas	✓*	✓	✓	✓		✓	✓				
	Non-green open space areas (plazas, paved public areas)	✓*	✓	✓				✓				
	Urban infrastructure areas	✓*	✓	✓				✓				
7. Mixed-use areas		✓	✓	✓	✓	✓	✓	✓	✓		✓	✓
8. Commercial and services areas		✓	✓	✓			✓	✓				
9. Office areas		✓*	✓	✓			✓	✓				
10. Transportation areas		✓	✓					✓				
11. Defense and security areas		✓*						✓				

Table 24 (continued)

Kawasan Lindung (Protected areas)												
1. Water bodies	Water bodies							✓		✓		
2. Protective areas for the areas beneath/below	Protected forest areas											
3. Local protection areas	Local protection areas	✓*						✓				
4. Green open space	Urban jungle	✓*		✓				✓				
	City park	✓*						✓				
	Cemetery/Burial ground	Not applied										
	Green belt											
5. Conservation areas	Nature sanctuary areas											
6. Cultural heritage areas	Cultural heritage areas	✓*		✓	✓			✓				
7. Mangrove ecosystem areas												

(Source: analysis)
* = HP for governmental bodies
Formal rights from BAL can be granted to a parcel in a zone as long as there are buildings or physical structures on it

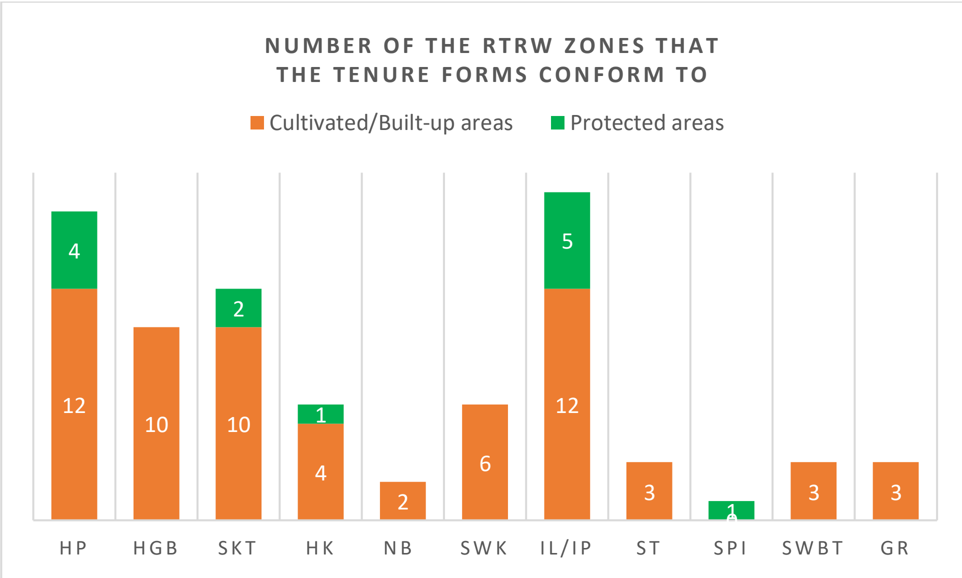


Figure 27. Number of the RTRW zones aligned to the tenure forms

3.3.3.2.2 Tenure conformity with coastal and small island spatial plan

As the Riau Islands Province does not yet stipulate the specific RZWP3K or RTRW at the provincial level that already integrates coastal zonation in its document, this thesis is using the generic zoning stipulation of coastal and small island plans (RZWP3K) in the analysis. RZWP3K has a validity duration of 20 years, similar to RTRW, and undergoes a review every five years. In RZWP3K, there are two main utilization areas determined by Law No. 27 of 2007 concerning Management of Coastal and Small Island Areas and put into detail by the Minister of Marine and Fisheries Regulation No. 28 of 2021 on Marine Spatial Planning Management.

1. *Kawasan Pemanfaatan Umum* (Areas for general usage). Area for general usage is a part of the coastal area that has been designated for various sectors of activity. This zone is equivalent to the built-up areas/cultivation areas in Law No. 26 of 2007 concerning Spatial Planning. As stipulated in Fisheries and Marine Affairs Minister Regulation No. 23 of 2016 on Management of Coastal Areas and Small Islands, this area consists of several zones, which are tourism, housing, service and commercial areas, salt production area, forest, mining, fisheries (fishing), fisheries (breeding), industry, public facilities, energy, and other usage.
2. *Kawasan konservasi* (Conservation areas). Conservation area is equivalent to the Protected area in Law No. 26 of 2007 concerning Spatial Planning. Conservation area consists of four types of usage:
   a. *Kawasan Konservasi Pesisir dan Pulau-Pulau Kecil*/KKP3K (Coastal and Small Islands Conservation Zone). KKP3K is defined as a part of the coastal area and small islands with specific characteristics that are protected to implement sustainable management of coastal areas and small islands. KKP3K is divided into smaller zones, that is Core Zone, Usage zone, and Other Zone.
   b. *Kawasan Konservasi Maritim*/KKM (Maritime Conservation Areas). KKM serves as conservation zones, with the aim of safeguarding maritime culture, traditions, and customs. The division of KKM is similar to KKP3K.

c. *Kawasan Konservasi Perairan*/KKP (Marine Conservation Areas). KKP are protected marine areas, managed with a zoning system, which is intended to realize fishing resource and environment in a sustainable manner. There are four classifications of zones in this area namely core zone, sustainable fishery zone, usage zone, and other zones.
d. *Sempadan pantai*/SP (Beach corridor border). SP refers to the land along the coastline, whose width is proportional to the shape and physical condition of the beach, and is at least 100 meters from the highest tide in the direction of the landmass.

3. Other than Areas for general Usage and Corservation areas, we also noted that there are two other important areas to be concerned, that are:
   a. *Kawasan Strategis Nasional Tertentu*/KSNT (Specific National Strategic Areas). KSNT are zones related to state sovereignty, environmental control, and/or world heritage sites, whose development is prioritized for national interests. In the Minister of Marine and Fisheries Regulation No. 28 of 2021 on Marine Spatial Planning Management, this KSNT area is put in Zonation Plan of KSNT (RZ KNST).
   b. Alur Laut/AL (sea lines). AL is the sea waters used for shipping lines, submarine cables, and migration routes of marine biota.

To assess the conformity between the suitable tenure forms and the RZWP3K zones, besides following the perspective from RTRW to maintain the harmony of those two planning systems, we also used some particular coastal regulatory-based perspectives as follows:

1. According to Article 18 of Minister of Fisheries and Marine Affairs Regulation No. 23 of 2016, the allotment of coastal waters up to 2 nautical miles is prioritized for conservation zones, living space, and access for traditional, small-scale fishermen; small-scale breeders; areas for small-scale salt production; coastal tourism; and public infrastructure. This regulation is the legal framework to assign the right to the people or maintain the existence of the customary tenure belonging to the people. In Article 36 of Minister of Fisheries and Marine Affairs Regulation No. 21 of 2021, the utilization of coastal waters less than 1 nautical mile from the coastline or with a depth of less than 5 meters is prioritized for activities ecosystem protection, traditional fishing, public access and beach, and defense, and also permitted with consideration for buildings and installations with residential, religious, social, and cultural functions, transportation and tourism facilities.
2. The Outermost Island as part of Sovereignty Boundary Zone is eligible to be certificated by the government through Right of Use (Hak Pakai). The subject of tenure is the government ministries. The government in 2017 and 2018 is targeting a certification of the 111 outermost islands of Indonesia.
3. In coastal waters, only for national strategic buildings, public facility buildings, particular tourism buildings, and housing for indigenous people, the statutory rights from BAL can be granted (Minister of ATR/Head of BPN Regulation No. 17 of 2016 on Land Management in Coastal Areas and Small Islands).
4. Based on Article 17 of Government Regulation No. 60 of 2007 on Conservation of Fishery Resources and Article 32 of the Regulation of the Minister of Fisheries and Marine Affairs No.17 of 2008 on Conservation Zones in Coastal Areas and Small Islands, continued by Regulation of the Minister of Fisheries and Marine Affairs No. 31 of 2021 on Management of Conservation Area (Article 11), the Core Zones aim to brings absolute protection of conservation, while the Limited Use Zones are for sustainable fishing areas. In Other Zones, the allowed activities is for fishery habitat rehabilitation, marine buildings and installations, port/mooring zones, ship traffic lanes, cultural zones, and other relevant zones.

5. According to Article 22 paragraph 3 from Minister of ATR/Head of BPN Regulation No. 18 of 2021 on Procedures For Establishing Management Rights And Land Rights, land rights are allowed to be assigned to *sempadan pantai* (beach corridor) with the obligation to maintain its function and a prohibition to change the area's utilization.
6. IL/IP can be assigned for a private tourism beach and the installation of submarine pipe and cables (Law No. 1 of 2014 Artice 16 concerning Management of Coastal Areas and Small Islands).
7. According to Permen KP No. 28 of 2021, IL/IP or KKPR, can be issued in conservation areas only if the proposed marine spatial utilization activity is explicitly permitted in the zoning plan, and supports or does not damage conservation functions. The granting of this tenure form within conservation areas will be strictly confined to non-extractive activities or those that are highly selective and sustainable, and which directly support conservation goals, including ecotourism, research, or ancillary facilities as stipulated within the zoning plan. Consequently, activities such as mining, the development of major infrastructure unrelated to conservation, or damaging intensive mariculture will not obtain this document. IL/IP cannot be given to the Core Zones in the conservation zones.
8. In Tourism Zone, the facilities and infrastructure can be built following the type of tourism.
9. In coastal areas, HGB can be used for the construction of supporting facilities for mining activities, such as rig, offices, warehouses, or employee dormitories.
10. Sea Lines Zone should be cleared from the activities and usage other than for research-related activities.

The results of the assessment can be seen in Table 25 and Figure 28.

Table 25. Conformity check of tenure forms with zonation in RZWP3K

Functions	**Allotment zones/Land use plan**	**Tenure forms**										
Kawasan Pemanfaatan Umum (Area for General Usage)		**HP**	**HGB**	**SKT**	**HK**	**NB**	**SWK**	**IL/IP**	**ST**	**SPI**	**SWBT**	**GR**
1. Tourism	▪ Seascape nature tourism							✓				
	▪ Beach	✓		✓	✓			✓				
	▪ Underwater tourism							✓				
	▪ Historical and cultural tourism	✓	✓	✓	✓			✓				
	▪ Water sport zone							✓				
2. Housings	▪ House	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓
3. Service and commercial		✓	✓	✓			✓	✓				
4. Harbours	▪ Port Working Area (DLKr) and Port Surrounding Area (DLKp)	✓*	✓					✓				
	▪ Fishing ports	✓*	✓					✓				
5. Salt production				✓				✓				
6. Forest	▪ Mangrove											
7. Mining	▪ Mineral (bauxite)		✓					✓				
	▪ Sea sand		✓					✓				
	▪ Oil and gas		✓					✓				
	▪ Geothermal		✓					✓				
8. Fisheries (fishing)	▪ Pelagic							✓				
	▪ Demersal							✓				
9. Fisheries (breeding)	▪ Marine breeding (Karamba/Floating Net Cages)							✓		✓		✓
	▪ Brackish water							✓		✓		✓

Table 25 (continued)

10. Industry	▪ Fish processing (factory)	✓	✓					✓				
	▪ Maritime manufacture	✓	✓					✓				
	▪ Biopharmacology	✓						✓				
	▪ Biotechnology	✓						✓				
11. Public facilities	▪ Educational facilities	✓*						✓				
	▪ Religious facilities	✓	✓	✓			✓	✓				
	▪ Public buildings (Sports)	✓*						✓				
	▪ Waterfront park	✓*						✓				
	▪ Gas station	✓*	✓					✓				
12. Energy								✓				
13. Others (in line with the bio-geo-physical characteristics)	▪ Anchor zone	✓*						✓				
Kawasan konservasi (Conservation Area)												
1. KKP3K	▪ Core zones											
	▪ Limited use zones							✓				
	▪ Other zones							✓				
2. KKM	▪ Core zones											
	▪ Limited use zones							✓				
	▪ Other zones							✓				
3. KKP	▪ Core zones											
	▪ Limited use zones							✓				
	▪ Other zones							✓				
*4. Sempadan pantai (*Beach corridor border)		✓*			✓			✓				

Table 25 (continued)

Kawasan Strategis Nasional Tertentu (Specific National Strategic Areas)												
1. Military Installation		✓*						✓				
2. Boundary Zone and Outermost Islands		✓*						✓				
3. Heritage Sites												
4. Endemic biota habitat												
Alur Laut (Sea Channel)												
1. Shipping lanes								✓*				
2. Submarine pipes/cables												
3. Migration route of marine biota												

(Source: analysis)

* = HP for governmental bodies, HP, HGB, HK can be granted to a parcel in a zone as long as there are buildings or physical infrastructures on it.

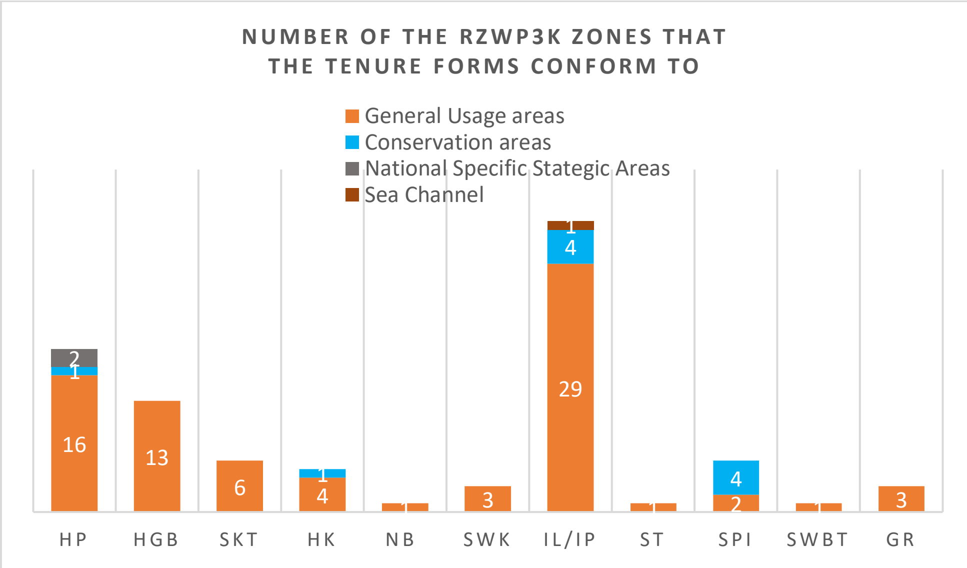


Figure 28. Number of the RZWP3K zones aligned with the tenure forms

3.3.3.3 Conformity to physical settings

A far as we are aware, no guideline made by the authoritative bodies of how to make tenure placement in coastal areas with regard to physical settings. Nonetheless, following the focus group discussion report about land management in coastal areas of five provinces in Indonesia (Southeast Sulawesi, Riau Islands, East Kalimantan, Papua, and South Sulawesi) by Puslitbang BPN (2010), we argue that two factors: type of land (i.e., submerged permanently or temporarily) and the integration to the landmass/the mainland, should be the determiners when placing tenure forms in aquatic land area. This thesis also takes Sofyan (2016) and Ismail (2012) point of view that the presence and the permanence of building are being another relevant on-ground-condition that affect tenure placement. Below is the argumentation and description of the situation of physical settings that this thesis proposes should be notified.

1. Presence of the building.
   BAL determines that statutory right assignation to the occupants in Indonesia is made possible if the land is guarded, used, cultivated, or built (Harsono, 2008). In the Minister of ATR/Head of BPN Regulation No. 17 of 2016 on Land Management in Coastal Areas and Small Islands, the building presence is clearly stipulated as an ultimate key parameter of the land to be considered as an eligible objects for land rights from BAL to people in coastal areas. In Article 1 of the regulation, a building defined as "a physical form of the construction work that is integrated with its ground, partially or wholly above and/or in land/or water, which functions as a place for humans to carry out their activities, whether for residential, religious, business, social, culture, and other activities". Therefore, with regard to the utilization, it is pertinent to consider the building presence as a determiner. The building indicates the concrete evidence of physical occupation. When in the hinterland the building is considered not legally part of the land (Heryani and Grant, 2004), in the aquatic land occurs the opposite situation: the building is recognized as part of the land. Thus, this thesis argues that, in aquatic land area, the object of tenure will be convincingly established by the presence of the building, or in the other words, the object of tenure will indeed appear strongly in the situation of building installation. There will be a differentiation of the proper tenure for vacant lands (defined as empty lands or non-building-use lands) and built-up lands. The buildings show further and concrete utilization (for example for shop-houses, warehouses, hotels, swift-nest buildings, restaurants, religious buildings; see Figure 29).

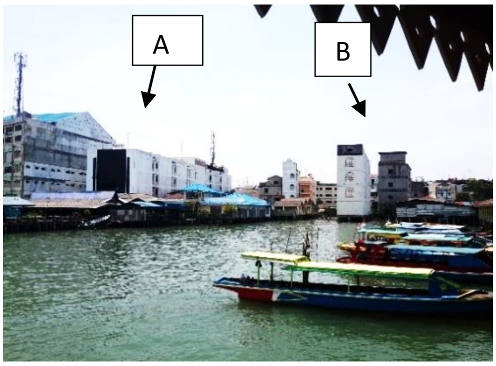
 Hotel (A) and swift (Collocalia Sp)-nest building (B)	 Resort
 A church in Bintan Island	 A port in Tanjungpinang Kota

Figure 29. Examples of the building utilization in the study area (Source: own collection)

2. PerPermanence of the building.
Duration of occupation also can be indicated by the building permanence (See Figure 30). A non-permanent building is a building made from of non-durable material (small woods, for example) or a building that is temporarily installed or a building that can be moved, whose useful time is not more than 10 years (Article 11 Law No. 36 of 2008 concerning Income Tax). The field observation reveals that in some coastline settlements it is common that non-permanent buildings will be just left after some years because the occupant wants to move elsewhere to get closer to their fishing areas or due to other reasons. Therefore, it is important to anticipate this circumstance by assigning the rights (in case of statutory forms) with a duration limit on it based on the permanence of the structure.

 A permanent house in Bugis Village	 A non-permanent house - and water-locked house - in Pelantar Pasar, Tanjungpinang Kota Village

 Abandoned buildings	 Water-locked warehouse

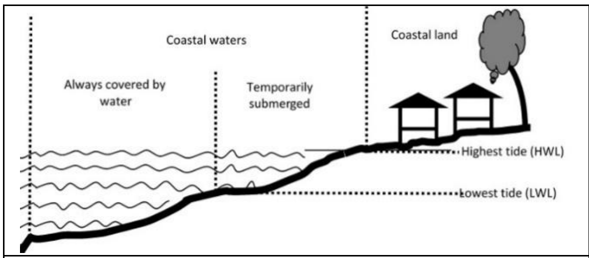
Figure 30. Examples of the condition of the building

3. Position of the parcel.
   a. Integration of the buildings with the mainland.
      The integration can be indicated by the connectivity of the buildings to the mainland through roads or connecting bridges. Based on this view, the buildings can be divided into water-locked buildings and connected buildings. The integration is also shown by the connectivity of the buildings to water-floor by the pillars stuck on the water-floor (as the representation of the surface of land) that support the buildings. According to this view, the buildings consist of floating and stilt buildings (Figure 31). In case the buildings are not connected to both situations (i.e., being the sea-locked and floating buildings) it is assumed that the tenure to the land is "weak", which affect which tenure forms that are suitable to place into (especially from land-based regime statutory tenure forms that do deal only with static occupation).

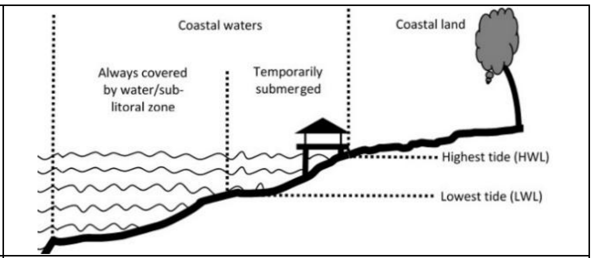
 Stilt houses	 Floating buildings

Figure 31. Stilt houses and floating buildings (Sources: own collections)

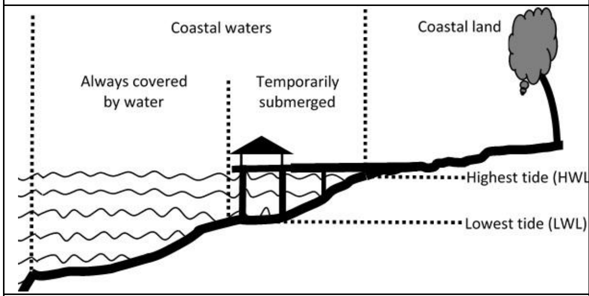
   b. The position of the property in the shallow waters that are permanently or just temporarily submerged (see Figure 32) The argument in this proposition is that a shorter time of tide indicates a more dominant character as land rather than as water and the best option for the rights is the ones from land-based regulations.



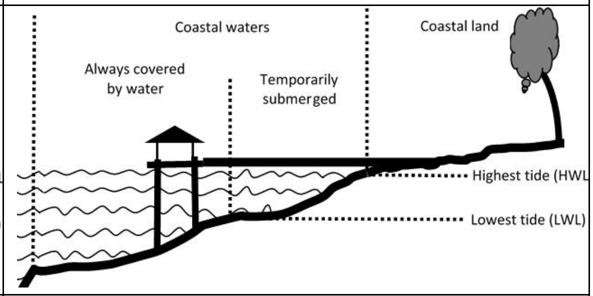
The buildings are located completely in the land-side of the coastal area (i.e., not in aquatic land).



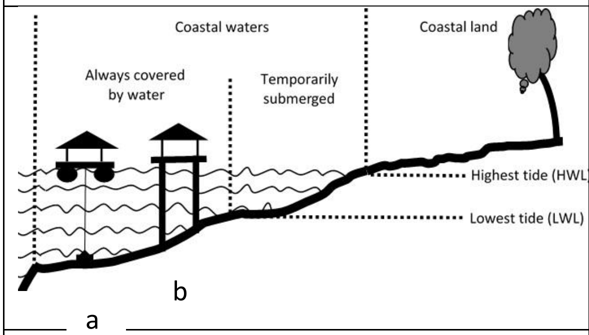
The building is a stilt building located in a part in land and the other part in water.



The building is a stilt building located in temporarily submerged are and connected to the mainland through a road or bridge.



The building is a stilt building located in the always-covered water and connected to the mainland through a road or bridge.



The building is (a) floating and water-locked and (b) stilted and water-locked.

Figure 32. Location of the buildings (source: author investigation)

Based on those above conditions this thesis arrange the possible settings of the aquatic lands parcels as

Aquatic land with buildings:

Setting 1	: Stilt, connected to the mainland, fully inundated, permanent building
Setting 2	: Stilt, connected to the mainland, fully inundated, non-permanent building
Setting 3	: Stilt, connected to the mainland, temporarily submerged, permanent building
Setting 4	: Stilt, connected to the mainland, temporarily submerged, non-permanent building
Setting 5	: Stilt, water-locked, temporarily submerged, permanent building
Setting 6	: Stilt, water-locked, temporarily submerged, non-permanent building
Setting 7	: Floating, water-locked, fully inundated, non-permanent building

Aquatic land without buildings:
Setting 8 : Fully inundated
Setting 9 : Temporarily submerged

Those settings can be depicted in Figure 33:

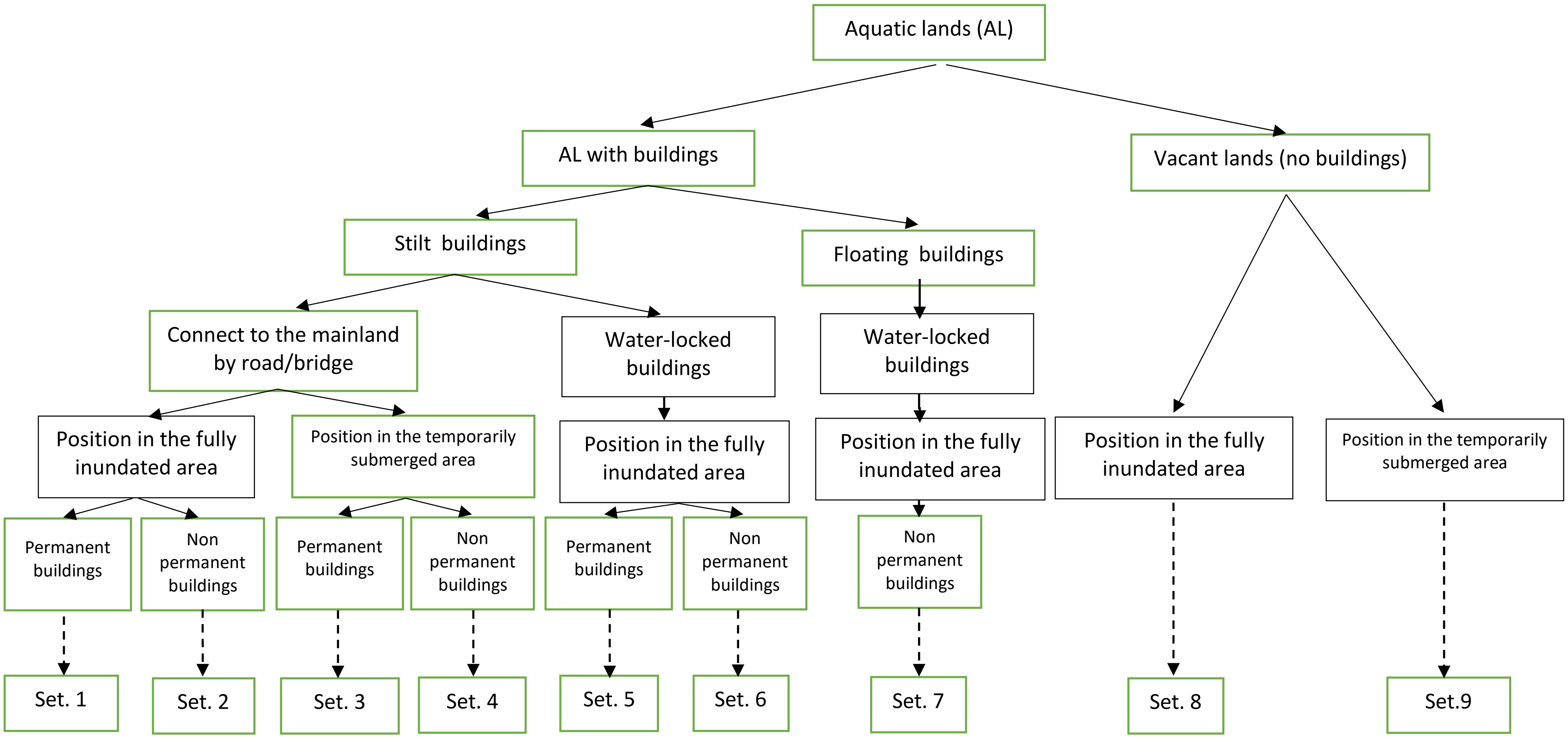


Figure 33. Physical settings of aquatic land parcels

To place the tenure forms into the settings, besides relying on the definition and the breadth of the usage of the tenure forms, the perspectives we used are:

a. Following the Minister of ATR/Head of BPN Regulation No. 17 of 2016 on Land Management in Coastal Areas and Small Islands, the land-based statutory tenure under BAL (i.e., HP, HGB, HP) is valid only with the the building installation. Other land-based tenure forms can be applied to either land with buildings or vacant lands.
b. The marine-based tenure is more applicable to vacant lands, although there may be buildings on it, for example, “bagan” (i.e., hut-like building to trap fish, store, and manually process the fish preservation).
c. The land-based statutory tenure forms are only eligible for the stilt buildings and the building connected to the mainland (regardless of its location in intertidal or fully inundated areas), and vacant lands in the intertidal areas.
d. Because no restrictions from the regulatory aspects, we argue that the non-statutory tenure forms are more flexible to be placed to each setting. Except for Surat Tebas and Grant that is not applicable to the fully inundated areas (Personal discussion with Bapak Rusli, Senggarang Village administrative official, 29 November 2016).
e. All land-based statutory tenure forms can be applied to permanent buildings in submerged areas and connected to the mainland.
f. According to a recommendation from Puslitbang BPN (2010), for the non-permanent stilt buildings located in the fully inundated area and intertidal areas, and have a connection to the mainland, the proper land-based statutory tenure form is the one that can accommodate less than 10 years of occupations, which is referring to HP.
g. The field observation reveals that the floating buildings are usually used for fishing structures, or “bagan”. The character of the bagan's occupation is mobile and dynamic, following the season and location of the fish catchment area. Floating buildings are generally water-locked, not permanent, and always located in the fully inundated area. Bagan usually lasts only a short time (a maximum of 3 months). It can be concluded that this type of dynamic and very short possession is not appropriate for most of the tenure forms that have been identified. However, if the building is located above the fishing area, the tenure form that can be allocated is IL/IP because then the tenure form is aimed for the fishing activities on the area and not just for the building.
h. In the research location, the water-locked building is usually functioned as a shelter for ship crews, ship landing, warehouse, and also for fishing activity. Its location is usually in the areas that are always flooded, meaning that the water-character is stronger than the land-character. Without the connection to the mainland, the more appropriate type of tenure forms is the ones from land-based tenure other than the ones from BAL.

Based on those point of view, the conformity matrix between the physical settings and the tenure forms is shown by Table 26 and the number of settings that match to the tenure forms is by Figure 34:

Table 26. Conformity check of the settings and the tenure forms

No	Setting	Tenure forms										
		HP	HGB	SKT	HK	NB	SWK	IL/IP	ST	SPI	SWBT	GR
1	1	✓	✓	✓	✓	✓	✓	✓			✓	
2	2	✓		✓	✓	✓	✓	✓			✓	
3	3	✓	✓	✓	✓	✓	✓	✓			✓	✓
4	4	✓		✓	✓	✓	✓	✓	✓		✓	✓
5	5			✓		✓	✓	✓			✓	
6	6			✓		✓	✓	✓			✓	
7	7							✓				
8	8							✓		✓		
9	9			✓				✓	✓	✓		✓

Note: for non-permanent buildings, the duration of HP is given for a period less than 10 years and can be extended and renewed if the building is changed into the permanent one.

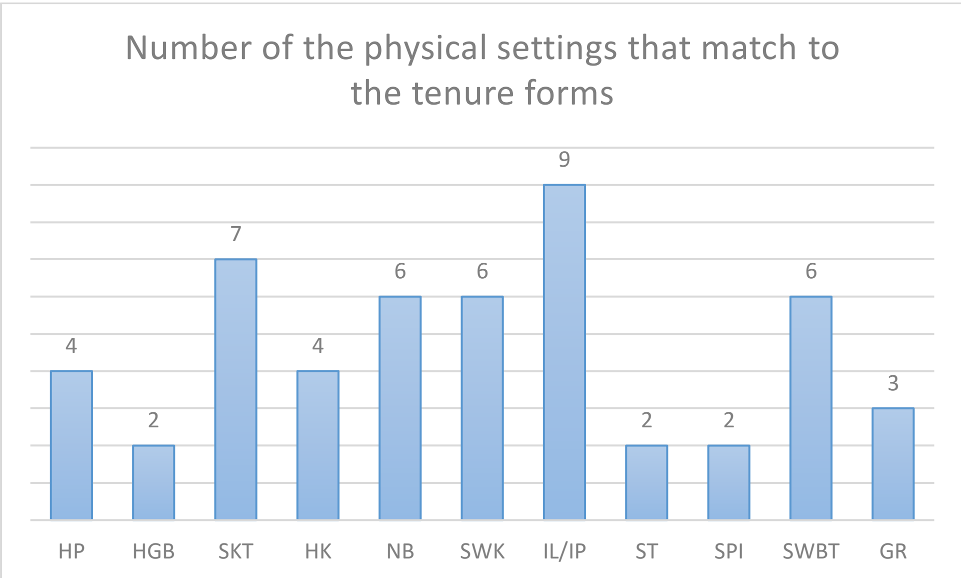


Figure 34. Number of physical settings that match to the tenure forms

3.3.3.4 Rights, restrictions, and resposibilities information of aquatic land parcels

Besides the classic juridical and physical data, the crucial attributes to be attached to the land are information about rights, restrictions, and responsibilities. The information is essential for managing a piece of land, especially in coastal areas, where there are multisectors involved in the utilization of land and its resources it can provide assurance and prevent the violations of the law in holding and using land. The term of rights is actually not merely referring to "what name of rights" but more to a benefit or claim entitling a person or entities that are owning or holding to be treated in a certain way with regard to land holding. Some examples of rights are possession (the right to occupy and control the land), use (the right to use the land for various purposes, such as residential, commercial, or agricultural activities, depending on zoning), transfer (the right to sell, lease, or otherwise transfer ownership of the land), and development (the right to develop or modify the land, such as constructing buildings or making improvements). These rights allow landowners to make decisions about how their land is used and to derive economic and personal benefits from it.

Restrictions can be expressed as a limit on the rights of the subject/owner/claimant when using and utilizing the land, or the attributes of land that are concerned with controlling use and activities on land and normally available through planning documents or general land use provisions. Restrictions also can be seen as limitations or conditions imposed on land use and development, often by government authorities, to quarantee that land is used in ways that are consistent with public policies, safety, and community interests. Some examples of restrictions are zoning laws (regulations that specify how land can be used (e.g., residential, commercial, industrial) and how buildings must be designed and situated), environmental restrictions (limits aimed at protecting natural resources, such as wetlands regulations, floodplain management, or conservation easements), building codes (standards for building construction), and easements (rights granted to others (e.g., utility companies) to use part of the land for specific purposes, such as running power lines or pipelines). Restrictions help manage land use in a way that protects public health, safety, and welfare; preserves environmental quality; and maintains the character of neighborhoods and communities.

Responsibilities pertain to the obligations landowners have to others and to society at large, which often arise from owning and managing land. Enemark (2009) defines responsibilities as "social and ethical commitment. Maintenance, compliance, taxation, and environmental stewardship are examples of responsibilities linked to land possession. Maintenance is known as the obligation to keep the property in good condition and does not pose a hazard to others. The owner also has obligations to pay property taxes and conduct environmental stewardship. The latter means managing land in a way that minimizes environmental impact, such as managing waste and conserving natural resources.

In summary, the concept of rights, restrictions, and responsibilities associated with land parcels encompasses a multifaceted legal framework that governs land ownership and use. The terms more or less describe the extent of all formal and informal interests that exist between people and land (Bennet, 2007). Rights give landowners the ability to use and enjoy their property, restrictions impose necessary limitations to align land use with broader societal needs and regulations, and responsibilities involve fulfilling obligations to maintain and manage the land in a manner that supports public good and compliance with laws.

The concepts of rights, restrictions, and responsibilities are crucial in understanding the use, management, and governance of land parcels. The administration of aquatic land parcels in Indonesia lacks comprehensive information about rights, restrictions, and responsibilities. Through a desk-based review and descriptive analysis, we examine published regulations to identify land entitlements, restrictions, and responsibilities that are important to landowners. We have identified some operational regulations that can guide us in determining rights, restrictions, and responsibilities related to land:

- Law No. 5 of 1960 concerning Basic Regulations on the Principles of Agrarian Affairs (BAL).
- Law No. 27 of 2007 jo. Law No. 1 of 2014 concerning Management of Coastal Areas and Small Islands (UU MPPPK).
- Law No. 6 of 2023 concerning the Stipulation of Perppu (Regulations in Lieu of Law) No. 2 of 2022 concerning Job Creation into Law.
- Government Regulation No. 18 of 2021 concerning Management Rights, Land Rights, Flat Units, and Land Registration (PP No. 18 of 2021).
- Government Regulation No. 21 of 2021 concerning Organization of Spatial Planning (PP No. 21 of 2021).

- Minister of ATR/Head of BPN Regulation No. 17 of 2016 Article (4) concerning Land Arrangement in Coastal Areas and Small Islands (Permen ATR/Head of BPN No. 17 of 2016).
- Minister of ATR/Head of BPN Regulation No. 18 of 2021 concerning Procedures for Determining Management Rights and Land Rights (Permen ATR/Head of BPN No. 18 of 2021).
- Minister of Marine and Fisheries Regulation No. 28 of 2021 concerning Marine Spatial Planning (Permen KP No. 28 of 2021).
- Circular Letter of the Minister of ATR/Head of BPN No. HT.03/757/VI/2022 concerning Guidelines for Implementing the Granting of Land Rights in Water Areas (CL 03/757/VI/2022).
- Decree of the Director General of Marine Spatial Planning No. 15 of 2023 concerning Guidelines for Implementing Facilitation of Approval of Conformity of Marine Spatial Utilization Activities for Local Communities in Coastal Areas and Small Islands (Decree No. 15 of 2023).

Using the findings from the analysis from Chapter 3 about tenure types, we examined the formal tenure types—HP, HGB, and HK—by thoroughly identifying and analyzing relevant clauses, norms, and statements from the aforementioned regulations to determine the rights, restrictions, and responsibilities.

According to the regulations, following Table 11, the detail of the eligible subjects for these rights are:

c. Individuals, such as indigenous, local, and traditional communities, who have settled in coastal waters or small islands for at least five consecutive years or ten non-consecutive years, are eligible. However, for HK, only communities are eligible (PP No. 18 of 2021). Individuals must have livelihoods as small fishermen, small fish farmers, marine tourism practitioners, or small salt farmers (CL 03/757/VI/2022).
d. Legal entities, institutions, religious and social bodies are eligible to HP and HGB. The first is usually tenured with HGB, while the latter three are tenured with HP.

The rights granted the owner the ability to (from PP No. 18 of 2021, Permen ATR/Head of BPN No. 18 of 2021):

a. Occupy the land.
b. Use the surface and use the airspace.
c. Utilize resources such as minerals and water.
d. Sell the land (not applicable to HK).
e. Transfer ownership and lease the land (not applicable to HK).
f. Mortgage the land (not applicable to HK).
g. Grant the rights (not applicable to HK).
h. Inherit the rights (not applicable to HK).
i. Divide (*pemecahan*), split (*pemisahan*), or merge (*penggabungan*) the parcels.

Some restrictions to the rights are (from UUPA, UU MPPPK, PP 18/2021, Permen ATR/Head of BPN No. 17 of 2016, Permen ATR/Head of BPN No. 18 of 2021), CL 03/757/VI/2022, Decree No. 15 of 2023, Permen KP No. 28 of 2021):

a. The rights are only allowed in areas with prior location determinations.
b. The rights are limited to built-up parcels. The use must follow spatial planning zones requirements.
c. Land abandonment is not permitted (BAL).
d. Blocking access or waterways is prohibited as it disrupts public mobility.
e. Damaging natural resources and environmental sustainability is not allowed.
f. Compliance with specific spatial intensity regulations or building codes is required, such as GSB (building boundary line), KLB (building floor coefficient), KDB (building base coefficient), KDH (green base coefficient), KTB (building site coefficient), KWT (built-up area coefficient), and building density. This information can be derived directly from the spatial planning documents, for example in the General Zoning Regulations section of the RTRW and in the Zoning

Regulations in the Detailed Spatial Plan (RDTR). They are linked to every stipulated land use plan.

g. If available, regulation about detailed spatial utilization. In RDTR, this information is stipulated in ITBX Table of Zoning Regulation. This table classifies the types of activities in each zone or subzone. I stands for di-***I**zin-kan* *(*Permitted): activities or land uses that are fully compliant with the zone or subzone's purpose, T stands for ***T**erbatas*, activities are permitted, but with specific restrictions. B is ***B**ersyarat*/Conditional, meaning the activities are permitted, but they must meet more complex specific requirements and often necessitate special permits or impact studies, such as the mandatory Environmental Impact Analysis (AMDAL). The last acronym, X, meaning Prohibited: the activities are not permitted and considered incompatible with the planned land use/the zone or subzone's purpose.
h. The parcel must meet minimum parcel size (*luas kavling minimum*) stipulated in detailed spatial plans. The minimum size rules are intended to support efficient land use and prevent land fragmentation.
i. Sales to legal entities or outsiders are prohibited.
j. The rights cannot be converted to HM.
k. Land must be occupied for at least 20 consecutive years by the owner or their ancestors (Permen ATR/Head of BPN No. 18 of 2021 Article 197).
l. Reclamation activities require permits from authorized bodies.

In the aspect of obligations, from those regulations we have identified several responsibilities of the landowner are as follows:

b. The owner must relinquish the land if it is used for public purposes.
c. The surrounding infrastructure must be maintained.
d. Environmental protection is mandatory.
e. Rights must be extended or renewed when required.
f. In small islands, public rights must be considered. Individuals cannot own the whole area of the island (PP No. 18 of 2021 Article 65).
g. The owner must be hand over the land to the authorities after the rights expire.
h. Buildings developed must align with designated purposes (e.g., housing, religious facilities, public and social facilities for HP and HK; housing and commercial facilities for HGB). It is not permitted to construct buildings whose usage does not align with the purposes allowed under the granted rights.
i. Facilities and infrastructure must be provided to prevent and control land fires.
j. KKPR is required for HP and HGB (Permen ATR/Head of BPN No. 18 of 2021 Article 197). According to Permen KP No. 28 of 2021, this is a document required for any activity involving the utilization of space within marine waters and jurisdictional areas.
k. Use environmentally friendly building materials.
l. After getting the rights, the development must begin within two years.
m. Technical requirements include registering the SK Penetapan and paying BPHTP and Land Taxes (PBB) for HP and HGB.
n. Boundary monuments or markings must be maintained, if applicable.

Management Right (HPL)—control rights from the state, with implementation authority partially delegated to the holder— is not listed as a type of land right by BAL and not as one of the applicable tenure rights for coastline settlements. Nevertheless, HPL may also be applied to a large area of land in coastal areas outside of the settlements.

The eligible subjects of HPL from the related regulations are:
a. Government bodies/national agency.
b. Regional/local agency.
c. State-owned /regional-owned enterprises (*Badan Usaha Milik Negara/Daerah*).
d. State-owned/regional-owned legal entities (*Badan Hukum Milik Negara/Daerah*).

e. Land Bank.
f. Stipulated legal entity.
g. Individuals (indigenous, local and traditional communities in coastal waters) for HP which the lands come from ulayat lands.

By owning the land, those subjects will have several rights to:
a. Arrange land use plans, allocate, use, and utilize in accordance with spatial planning.
b. Use and utilize all or part of the area or in collaboration with other parties.
c. Determine rates and/or annual mandatory fees from other parties in accordance with the agreement.
d. Within the scope of cooperation, the area could be given land rights of HGU, HGB, HP.
e. Land Rights on HPL in collaboration with other parties can be given Mortgage (HT), be transferred, or be released to other parties.

The restrictions linked to HPL are:
a. HPL cannot be used as collateral for debt burdened with mortgage rights.
b. HPL cannot be transferred to other parties.
c. HPL only can be released to HM, released for public interest, or other provisions stipulated in laws and regulations.
d. In the area of HPL, it is not allowed to erecting permanent buildings that reduce function as the conservation area.
e. HPL cannot be implemented for derivative registration (transfer of rights, imposition of mortgage, or split, separation or merger) if the Management Rights have been granted Land Rights.

The responsibilites of the HPL holders are:
a. Releasing land if it is used for public purposes.
b. Maintain surrounding infrastructure.
c. Protect the environment.
d. Extend or renew rights.
e. Hand over the land after the rights to the land are erased.
f. Develop buildings only for housing, religious facilities, public and social facilities (commercial buildings are not allowed).
g. Provide facilities and infrastructure for preventing and controlling land fires.
h. Land rights in small islands must consider public rights.
i. Have received KKPR.
j. Using environmentally friendly building materials
k. Carry out development on the land in accordance with the purpose and requirements as stipulated in the decision to grant the rights no later than 2 (two) years from the date of stipulation.
l. Reporting at the end of each year regarding the use and utilization.

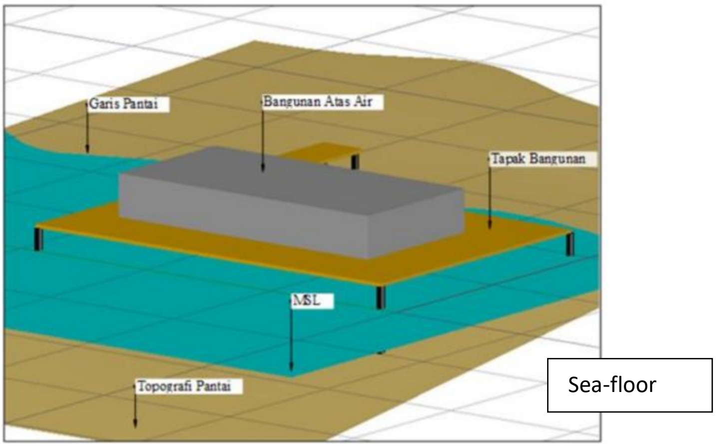
4 UAV SYSTEM FOR AQUATIC LAND BOUNDARY ACQUISITION

4.1 INTRODUCTION

A secure claim of a piece of land through a proper land right cannot stand alone without a reliable boundary that presents and affirms it spatially. Relying on that point, this chapter is dedicated to presenting our works in addressing Objective 2 on the utilization and assessment of Unmanned Aerial Vehicles (UAVs) as one of the fit-for-purpose technologies to support the determination of cadastral boundaries of aquatic land parcels in the context of land registration.

4.1.1 Defining the boundary of aquatic land parcels

As explained in the introduction part, the characteristic of aquatic land area brings complexity about what and how the boundary should be represented (e.g., physically demarcated or just delimited) in accordance with the types of tenure forms and cadastral contexts. This thesis will first clarify this matter before proceeding further. The clarification also gives insights to later choose the relevant boundary for the fit-for-purpose approach. For the purpose of this chapter, we adopt the description from Jing et al. (2001) that states a boundary as a line, extracted from either natural features or man-made constructs, marking the bounds of two neighboring parcels of land tenure. The boundary of land parcels can be defined by physical demarcation (i.e., marking and measurement of the marks) on the ground or by a mathematical description based on a coordinate system (International Federation of Surveyors (FIG), 1995). The boundary lines (also commonly called property lines) define the extent of the legal limits of tenure of any parcel of land (Donnely, 2014), or according to Tamtomo (2006), define the "boundary of tenure", which can be physically demarcated by means of monumentations or imaginary created by means of map.



Note: The depth is measured from the sea-floor (Zeindwinanda, Djunarsyah, and

Figure 35. 3D model of a building in water environment that incorporates vertical dimension.

The boundary of a plot of land or property needs to accurately reflect its geometry and represent the tenure dimension embedded in it. If there is a vertical dimension and different vertical stratum of possession, which correspond to vertical multiple and parallel applied rights in its physical layers, ideally the boundary and the tenure registration are not just two-dimensional or in other words, they incorporate the third dimension, either heights or depths (Ng'ang et al., 2014, Tamtomo, 2004). In the intertidal zone, the geometry of the parcel is vague by nature because there are certain periods when the parcel is completely in the form of dry land (showing dominant 2D character, with no sign of depth-vertical dimension from the water surface), and at other times the parcel is covered by water (showing dominant 3D character, with the presence of depth-vertical dimensions). From our field observation, it is obvious that the use-based occupation in the intertidal zone shows non-strata possession in its physical layers (i.e., water surface, water column, and sea floor); only one layer of occupation in a certain time. The occupation only happens either just above water (for houses) or just in water column (for fish breeding). No particular occupation for the sea-floor, except for placing the pillars of the house. Therefore, in defining the horizontal boundary of an aquatic land parcel, this thesis only approaches it through a two-dimensional (planimetric) representation. It is also in line with the operationalization of the existing cadastral system in Indonesia, which places the legal representation of the parcel boundary in the current land registration system is still in the form of two-dimensional (Rusmawar et al., 2012), except for the possession of multi-storey apartments or flats (Indonesian: *rumah susun*).

Nevertheless, this thesis realizes that in the fully inundated areas, the volumetric characteristic appears constantly in the presence of permanent depth (see Figure 35) that allows the permanent use of water columns. It makes the boundary of tenure could be approached not in two dimensional way (Ng'ang et al., 2014). The representation may take 2,5D (2D parcel but tagged with heights/depths information in the registration map) or in full 3D (geometry and rights registration are 3D) for a tenure form like IL/IP that makes the boundary a combination of horizontal and vertical water boundaries, accommodating the strata of occupation, and also the maximum depth of every tenure can be located (Ariyanto, Astor, and Sidqi, 2019). However, as mentioned in the prior paragraph, this thesis is focusing on the planimetric view, and thus, this volumetric boundary determination, which is based on the concept of 3D cadastre, is out of topic.

As shown before, in general, the parcels (or, in land administration disciplines, also called tenure objects) can be divided into two types: the parcels with buildings (built-up parcels) and the parcels without buildings (vacant parcels). Thus, we analyzed each type separately. This thesis goes into more detail about the demarcation (physical confirmation of the boundary) and delimitation (legal agreement about the boundary) sides of setting those boundaries. It also discusses the boundary's fitness by two different types of cadastral boundaries, which are fixed and general boundaries.

4.1.1.1 What are the boundary of built-up parcels?

To avoid complication, the buildings here refer to stilted buildings (static buildings, not floating or moveable buildings)

Boundary of the rights from BAL

It has been mentioned that land rights in Indonesia exist if there is use and utilization by people (Harsono, 2008), and one of the most solid proofs of use is the building installation. Nonetheless, as stated in the Minister of ATR/Head of BPN Regulation No. 17 of 2016 on Land Management in Coastal Areas and Small Islands, for aquatic plots in the intertidal zone, the existence of buildings is more than just solid evidence: it is a key factor and, at the same time, becomes a limiting factor of placing land tenure originating from BAL. It is a limiting factor because "rights can only be granted into a utilization in the form of building" (Article 5 Paragraph 1), and, about the exact position of the boundary, Article 5 Paragraph 3 on land management in intertidal zones further points that:

> *Batas bidang tanah sebagaimana yang dimaksud pada Ayat (1) ditentukan berdasarkan melalui proyeksi titik-titik sudut terluar dari bangunan di atasnya yang diberi tanda batas.*
>
> The boundary of the parcel as referred to Paragraph (1) is determined based on the projection of the outermost vertices of the building above with markers on it.

This legally binding rule clearly defines that the tenure of built-up parcels cannot exceed the outermost vertices of the building (perimeter of the building footprint). Hence, we can say that boundary of BAL's tenure is the perimeter of the building footprint (or just called building footprint). The building footprint, defined as the surface area occupied by the building structure, can be delineated in two ways: by projecting the outermost boundaries of the building's rooftop or by tracing the outermost structural elements that extend beyond the roofline (see Figure 36). This approach, which captures the full extent of the building's footprint, is relevant to the perspective adopted in how remote sensing techniques work (Zeng et al., 2013; Vicini et al., 2014).

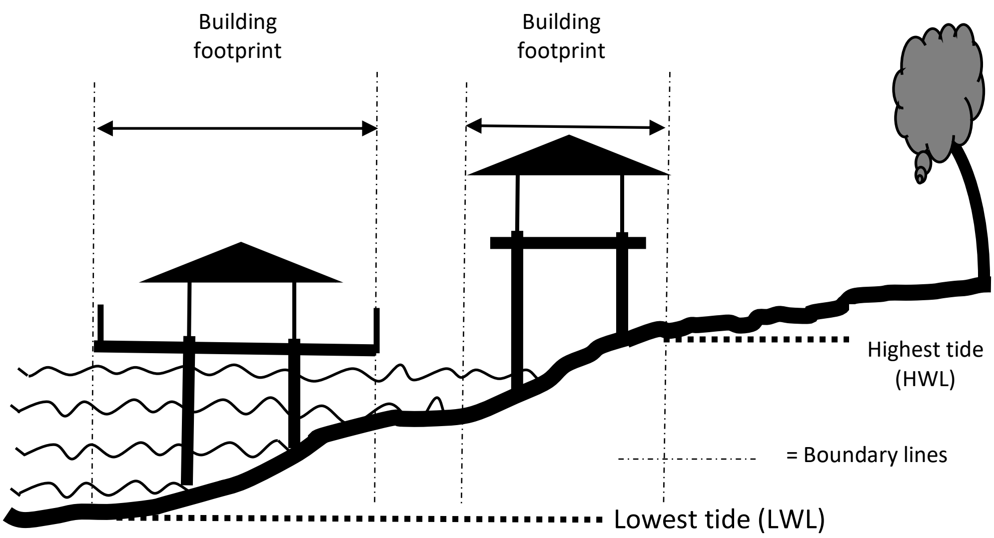


Figure 36. Visualization of the boundary of built-up parcels

In fully inundated areas, the Minister of ATR/Head of BPN Regulation No. 17 of 2016 on Land Management in Coastal Areas and Small Islands does not explicitly regulate the exact location of the boundary of the plot with the building. However, a land certificate, in principle, should be established based on three components: the subject of the rights (persons), juridical data in terms of the paper-based possession, and physical data (i.e., spatial attributes), which is definitely related to the boundary and physical evidence. The current accepted and agreed conception of land parcel boundary in National Land Agency (BPN), the authoritative body that can issue the tenure forms from BAL, is that the boundary should be the one that is physically apparent and demarcated (Santoso, 2010). Therefore, this thesis proposes that the boundary of a fully inundated parcel with a building is also the outer side of the building footprint (Table 27).

Tenure forms not from BAL

In the intertidal zone, with respect to the view about the importance of physical evidence, besides the building footprint, the boundary can also be represented and physically demarcated by fences or lined-up pillars. For fully inundated areas, apart from the building footprint, the boundary should be an imaginary line in the vacant area outside the building. The line shows the outermost utilization line as administratively stated in the document of possession or in the agreement.

Table 27. Suitable tenure forms and their boundaries in built-up aquatic land

Area	Suitable tenure forms and their boundaries in built-up aquatic land			
	BAL	Boundary	Non BAL	Boundary
Temporarily submerged	HP, HGB, HK	Building footprint	SKT, NB, SWK, ST, SWBK, GR	Building footprint, fences, pillars
Fully inundated	HP, HGB, HK	Building footprint	SKT, NB, SWK, SWBK	Building footprint, imaginary

Source: Author's analysis

4.1.1.2 What are the boundaries of vacant aquatic land parcels?

Usually the water in intertidal areas is shallow, less than 4 meters deep as shown by a study from Simanjuntak et al. (2016) or even by definition only a maximum of 2 meters deep (Basith, 2014) which allows marking or monumenting the boundary in the condition of no public use on it. The appearance of dry land is also usual in the zone, especially for the areas that are having only a short period of inundation. Therefore, as shown in Table 28, this thesis suggests that a vacant plot's boundary should also be physically defined through demarcation. But, without any buildings, the possible physical markers for the plot are fences or pillars.

In fully inundated areas, to adapt to the dynamic of water environment, rigorous physical boundaries such as lined-up pillars and stacked stones are not well suited. As stated by Ng'ang: "in the case of the marine cadastre, this might not be possible as placing monument points in marine space presents quite a challenge" (Ng'ang et al., 2014, p. 448). The possible type of boundaries we propose to define the tenure or landholding in the areas are as follows:

1. Virtual boundary. It is similar to an imaginary boundary. The boundary does not need physical markers and only appears mathematically in the form of coordinates (with a certain tolerance of accuracy) set forth on a map or other possession document. The boundary is not physically demarcated, only delimited among involved parties.
   An example of this is the boundary of IL/IP. As a formal tenure form from coastal areas and small islands regulation, it is clearly stipulated in Location and Management Permit for Coastal Waters and Small Islands Minister of Marine and Fisheries Regulation (KKP, 2019) that

   > *Izin lokasi perairan pesisir diberikan dalam batas keluasan dan kedalaman tertentu yang dinyatakan dalam titik koordinat geografis pada setiap sudutnya.*
   >
   > Location Permit for coastal waters is given in a certain extent and depth which is stated in a geographical coordinate for every corner point of it.

   Thus, the shape of an area is normally defined pragmatically as a two-dimensional figure in either rectangular, parallelogram, or triangle shape (Ariyanto, Astor, and Sidqi, 2019). In case a physical marker is necessary to determine the coordinate of the boundary, a monumentation can be placed in the mainland as a reference point to define the coordinate of every bend of the parcel through distance and bearing measurement.
2. Especially for some landholdings like fish farms or seaweed cultivation, the boundary can also be "demarcated" imprecisely by placing a buoy in every bend of the parcel.

Table 28. Suitable tenure forms and their boundaries in vacant aquatic land

Area	Suitable tenure forms and their boundaries in vacant aquatic land			
	BAL	Boundary	Non BAL	Boundary
Temporarily submerged	Do not apply		SKT, IL/IP, ST, SPI, GT	Fences, pillars
Fully inundated	Do not apply		IL/IP, SPI	Virtual/imaginary, buoys

Source: Author's analysis

Boundary determination must account for not only identification and demarcation but also the following cadastral contexts:

1. When a road crosses a plot of land in Indonesia, the abuttal principle does not follow the *ad medium filum* rule: the ownership of the plot extends to the middle of the road (Donnely, 2014). As a conventional rule, the plot is described as being bounded by the road; the possession stops at the edge of the road because the road automatically belongs to the state once constructed. All types of tenure forms should adhere to this common rule. If a road passes through and divides a parcel into two pieces, these pieces are considered separate parcels, and the road defines their boundaries.
2. Delimitation (boundary agreement between involved parties).
   In ordinary land area, the delimitation process in Indonesia is specifically following *Contradictoire Delimitatie* principle, which is regulated in Government Regulation No. 24 of 1997 concerning Land Registration. It stipulates that the placement and establishment of the

boundary must be relied on a written and signed agreement between the landholder and their bordering neighbors (Santoso, 2010). The notion behind this formal and juridical agreement is about approval and recognition of claim, which is not only formally coming from the government, but also from the bordering neighbors. This principle is an obligatory prerequisite for boundary measurement and land registration to get tenure forms from BAL (Arief, 2018). It is not known and thus not pertinent for the tenure forms whose sources are not BAL, except for IL/IP. As stated in the Governor of West Sumatra Regulation No. 51 of 2018 concerning Procedures for Giving Location Permit and Management Permit of Coastal Waters, for example, there should be a letter from the other users nearby that states that they have no objection against the proposed claim and its boundary.

3. Land administration offers two primary approaches to boundary establishment: fixed boundaries and general boundaries (Dale and McLaughlin, 1999). There are several notions about the difference between fixed and general boundaries, such as legal binding and documentation. This thesis adopts the understanding from FAO (2003), which states that fixed boundaries are called fixed as “they are merely delimited more precisely” (p. 84). Fixed boundaries, or sometimes also called specific boundaries, are those that are determined accurately by a professional land surveyor, mostly by terrestrial surveys. The boundary corners can also be traced accurately once lost because boundary corners are demarcated through monumentation and coordinated precisely (Tuladhar, 1996). Dale and McLaughlin simply define general boundaries as the approximate line(s) of the boundary, either demarcated by existing physical features, coordinated visually (visual boundaries), or measured in less precise (accommodating more tolerance of accuracy).

Table 29 resumes our definition of the aquatic land parcel boundary.

Table 29. Boundary of aquatic land parcel

* = only occur if the boundary markers are made large enough to be visually recognized and coordinated using very high spatial resolution imagery

No	Aquatic land boundaries	Contradictoire delimititae?	Probable approach for boundary determination				
			Fixed boundary		General Boundary		
			Physical demarcation	Coordinated precisely	Physical demarcation	Coordinated visually	Coordinated less precise
1	Aquatic lands with building						
	a. Tenure from BAL Temporarily submerged and fully inundated area: physical object (building footprints)	Yes	Yes	Yes	Yes	Yes	Yes
	b. Tenure from Non BAL : Temporarily submerged and fully inundated area: ▪ Physical object (building footprints, fences, pillars)	No	Yes	Yes	Yes	Yes*	Yes
	▪ Imaginary/virtual (paper-based, no monumentation).	No	No	No	No	No	Yes
2	Vacant aquatic lands						
	a. Tenure from BAL	Tenure forms from BAL do not apply					
	b. Tenure non-BAL : ▪ Temporarily submerged: - Physical objects (fences, pillars)	No, except for IL/IP	Yes	Yes	Yes	Yes*	Yes
	▪ Fully inundated: - Imaginary/virtual (paper-based, no monumentation).	No, except for IL/IP	No	No	No	No	Yes
	- Physical (floating buoy).	No, except for IL/IP	Yes	No	Yes	Yes*	Yes

Relevant boundaries under fit-for-purpose cadastral survey system

As mentioned in Section 2.4, fit for purpose land administration, there are three frameworks used in the fit-for-purpose approach: spatial, legal, and institutional frameworks. When deploying a cadastral survey system for boundary acquisition, the framework we should refer to is the spatial framework with its principles; that is:

1. General boundaries rather than fixed boundaries.
2. Aerial imagery rather than field surveys. This principle prioritizes the use of aerial or satellite imagery for identifying the way land is occupied and used—rather than using field surveys—for extracting information about land parcels, such as the boundary coordinate, area, and shape.
3. Accuracy related to the purpose rather than technical standards. This principle, intrinsically linked to the preceding two, posits that the accuracy of land information should be defined in relation to its intended purpose. Then, it is implied that the accuracy should be fit for purpose in terms of it being accommodative to local and national survey standards and guidelines rather than just to rigid universal standards. This principle also says that "the scale and accuracy of the aerial imagery should relate to purpose and will therefore vary according to topography and density of development" (p.19).

However, the fit-for-purpose approach cannot be applied with the same level of applicability to different types of aquatic land parcels:

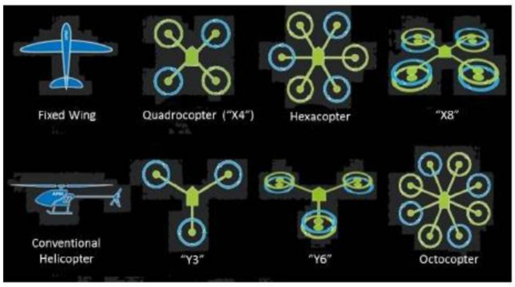
- The approach is very applicable to the parcels whose boundaries are physical in the form of building footprints or roads, but might be less applicable to fences, pillars, and buoys unless they appear as distinctive as the buildings in the imagery.
- From the images, the non-physical/imaginary boundaries cannot be directly visually generated in the form of coordinates. The imagery still can be helpful to indirectly obtain the boundary coordinates in an additional activity, for example, in a participatory mapping process, with a situation where there is a prior consensus deciding that the boundary location is defined by certain rules, such as an imaginary median line between two buildings or a specific distance from a certain physical mark.

Consequently, the measurement using fit-for-purpose technology in this thesis will prioritize the building footprint as the tenure boundary. From the previous analysis, it is known that the building footprint is the boundary of BAL tenure forms. Hence, in other words, we can also say that the boundary we want to determine and assess its reliability in this thesis is the boundary of tenure forms from BAL, which brings the consequence that the standards we take are the ones that relate to these tenure forms (not from some standards from IL/IL regulations, for example).

4.1.2 UAVs for cadastral boundary acquisition

The fit-for-purpose approach recommends the use of general boundaries generated from imagery to support land registration. In recent development, one emerging system for this call is an unmanned aircraft system that provides aerial imagery. Many terms have been used to describe the system. As mentioned in Turner et al. (2016), it may have been called Drones, Unmanned Aircraft System (UAS), Unmanned Aerial Vehicles System (UAV system), Remotely Operated Aircraft (ROA), Remotely Piloted Aircraft (RPA), Remotely Piloted Aircraft System (RPAS), and Unmanned Vehicle System (UVS). Following the Federal Aviation Administration/FAA (2008), this thesis will use UAVs. A simple definition of the term was given by Dalamagkidis (2015c): UAVs refer to a pilotless aircraft, a flying machine without an on-board human pilot or passengers. The aircraft, or Unmanned Aerial Vehicles (UAVs) can be controlled remotely, semi-autonomously, and autonomously, or a combination of them (van Blyenburgh, 1999). It has some equipment such as cameras, positioning tools, communication equipment, and other tools that make it a unit that functions as an airborne remote sensing system, or according to Eisenbeiss (2009), it is a new photogrammetry system that is equipped with a photogrammetric measurement system that introduces near real-time application and low-cost alternatives to the classical manned aerial photogrammetry.

As a system, UAVs have two main components: airborne/aircraft and ground component (Elkaim, Adhika, and Lie, 2015). The aircraft functions as the platform where a camera and other sensors are installed to capture images. The ground component, which is called Ground Control Station (GCS), is the component that prepares, controls, and navigates every airborne movement and activity. Classically, the unmanned aerial system can have various types of vehicles, for example, air balloons, kites, and wing-based aircraft. The aircraft itself is normally divided into two categories (see Figure 37): the multicopter, or rotary wings, or VTOL (Vertical Take-Off and Landing), and the fixed-wing (Barnes et al., 2014). The rotary wings are based on rotors and blades, and they often have four or more rotors. Their flight characteristics are best compared to a helicopter. The fixed-wing has the characteristics of a traditional aircraft, made of an airplane body that has a single propeller and two wings. Presently, a third type of aircraft has appeared: the hybrid drone. It is an integration of a rotary wing and a fixed wing, having the vertical take-off and landing capabilities of helicopters and the efficient cruising of aeroplanes.



Common UAV platform (Source: Barnes et al., 2014)

Example of a hybrid drone (Source: Unmanned System Technology, 2018)

https://www.unmannedsystemstechnology.com/2017/09/phoenix-lidar-jouav-announce-hybrid-long-distance-lidar-mapping-uav/

Figure 37. UAV types

As a remote sensing system, or more precisely, non-satellite remote sensing or aerial photogrammetry/aerial sensing, UAVs are growing to be a widely used in many applications outside military surveillance (Dalamagkidis, 2015b). A case of the civil activities using UAVs that they are now applied for forestry, precision agriculture, cargo, community mapping, hazard and disaster, environmental surveying and monitoring, search and rescue (SAR), wildlife monitoring, archaeology, and public utility management and monitoring. UAVs have one major advantage in their ability to be relatively flexible in accessing remote areas or difficult landscapes without physical limitations (Eisenbeiss, 2009), at which point the ground survey is limited, to provide cloud-free and high temporal and spatial resolution information (Remondino et al., 2011). UAVs technology also opens an opportunity for geospatial sectors, either governmental bodies or private sectors, especially in developing countries, to produce their own imagery data as an alternative to satellite imagery, which is mostly produced by big providers from developed countries.

Although initially, UAVs were not yet common in Indonesia land registration system due to the old paradigm that focused on conventional photogrammetry, it is currently growing to be a potential system that could support land parcel boundary data acquisition. The high cost of the ground measurement, manned classical photogrammetry, and high-resolution satellite imagery, as well as the cloud cover problem of satellite imagery, which is common in a tropical country like Indonesia, become the pushing factors. A rule of thumb for implementing this technology is if the area is not efficient for conventional/manned photogrammetry (i.e., <10.000 hectares) and as so for terrestrial survey (i.e., 250 hectares), or there is a demand for rapid response and recovery land administration (due to disputes or disaster, for example) the UAVs could be an alternative (Rochmana, 2016).

Radjawali and Pye (2015) investigated the use of this technology for indigenous territory fights against land grabbing. Mumbone (2015) argued that UAVs are useful for mapping boundaries for adjudication purposes of customary communities, while Ramadhani et al.'s (2018) study revealed that they have potential for registering agricultural land parcels. Despite having limiting factors on image orientation accuracy, UAVs can quickly map the surface of areas at low flying altitudes with good spatial accuracy (Manyoky et al., 2012).

The development of semi-automatic techniques for mapping feature edges that can minimize human intervention is becoming an additional gateway to support fast general boundary extraction for reducing time-consuming land registration. It is because, even while the orthophoto generation has been done, we still need another step for transforming. Generally speaking, this technique has been proven to be effective for road network extraction, farmland boundary delineation, and river boundary delineations as shown by Eker et al. (2021) and Babawuro and Beiji (2012). Extending this application for mapping the cadastral boundary in the form of a rooftop or building footprint (following the stipulation from the Minister of ATR/Head of BPN Regulation No. 17 of 2016 on Land Management in Coastal Areas and Small Islands) appears to be a real opportunity for answering the call for the fit-for-purpose approach that focuses on speed, better coverage, and scalable accurary. Moreover, because in the coastline water areas, conventional terrestrial surveys, for example, GNSS Geodetic or Total Station measurement, are not fully suitable due to inflexibility for placing the equipment in a steady measuring position, the usability of UAVs find the momentum. Nonetheless, it is also noticed that UAVs may need a high cost in the first installment (Shofiyanti, 2011), still have a limitation of flight endurance, payload, and stability, and may face uncertainty results against terrain conditions (Crommelinck et al., 2016). Therefore, the assessment regarding operability and product reliability of UAVs is important to be conducted in such areas to understand how further this technology can produce reliable general boundary.

4.1.3 Research activities

The research process of this section has three main phases: review, develop and utilize the survey system, and evaluate it. In the review phase, this thesis defined the boundary of aquatic land parcels and reviewed the need of UAVs in the Indonesian context related to policies, regulations, and constraints. Based on the review, the approach was developed and applied in the case study area. We conducted two main activities in this second phase: fieldwork and digital photogrammetry. The fieldwork included field reconnaissance and flight planning, image acquisition, and control points collections using GNSS/GPS static survey. After the fieldwork, digital photogrammetry activities were carried out to generate orthophotos as the aimed product of UAV survey in this thesis. Our approach in generating the orthophotos is a photogrammetric range imaging techniques called Structure from Motion (SfM). In the last phase, an evaluation was carried out to assess the performance of UAVs on the basis of fit-for-purpose elements. We assessed the attainability and affordability of the UAV system and the reliability of its generated products. The reliability assessment was conducted to check whether the geometric accuracy of the orthomosaic fulfills the accuracy requirements of cadastral base map, to recognize the optimum scale of the map, and to discern the accuracy level of the extracted general boundary that will be used as the boundary of tenure. The general boundary extraction was conducted using on-screen delineation and semi-automatic extraction (i.e., an object-based approach or segmentation).

4.2 UAV SURVEY

4.2.1 Vehicle selection

Each UAV has its advantages and weaknesses regarding some aerodynamic and physical features. These include flexibility in take-off and landing, range, endurance, weather wind dependency (stability against wind/wind resistance), maneuverability, and payload capacity (Eisenbeis, 2009, Nex and Remondino, 2013). The technology can change over time, but it is commonly known that the fixed-wing has advantages in range and endurance (Mesas-Carrascosa et al., 2014). Their payload capacity enables them to carry durable batteries, extending flight time to three to four times longer than most multi-rotor drones, which typically fly for only around 30 minutes in ideal weather conditions on a single battery cycle. The UAVs with fixed wings also have higher cruising speeds, enabling them to fly more stably against the wind after take-off, but they are less maneuverable, have less resistance to wind disturbance, and demand more space in the taking-off and landing process compared to the multicopters. The extent of AOI matters when choosing the vehicle. This thesis has the UAV survey AOI of more than 400 hectares and thus needs a flight that can cover a large area in one single battery cycle. Mumbone (2015) denotes that in an area of more than 100 hectares, fixed-wing vehicles are a better choice than rotary wings. Our reconnaissance tells us that the area is flat and large enough, so high maneuverability is not necessary. Flight stability during image capturing is important as the wind is strong considering its location on the coastline. Deploying a fixed-wing vehicle becomes more appropriate in such a situation. Table 30 dan Figure 39 shows the UAV fixed-wing specifications that were used for this study. Figure 38 shows the steps taken and the methodology that was used to reach the second goal and answer the research questions that went with it.

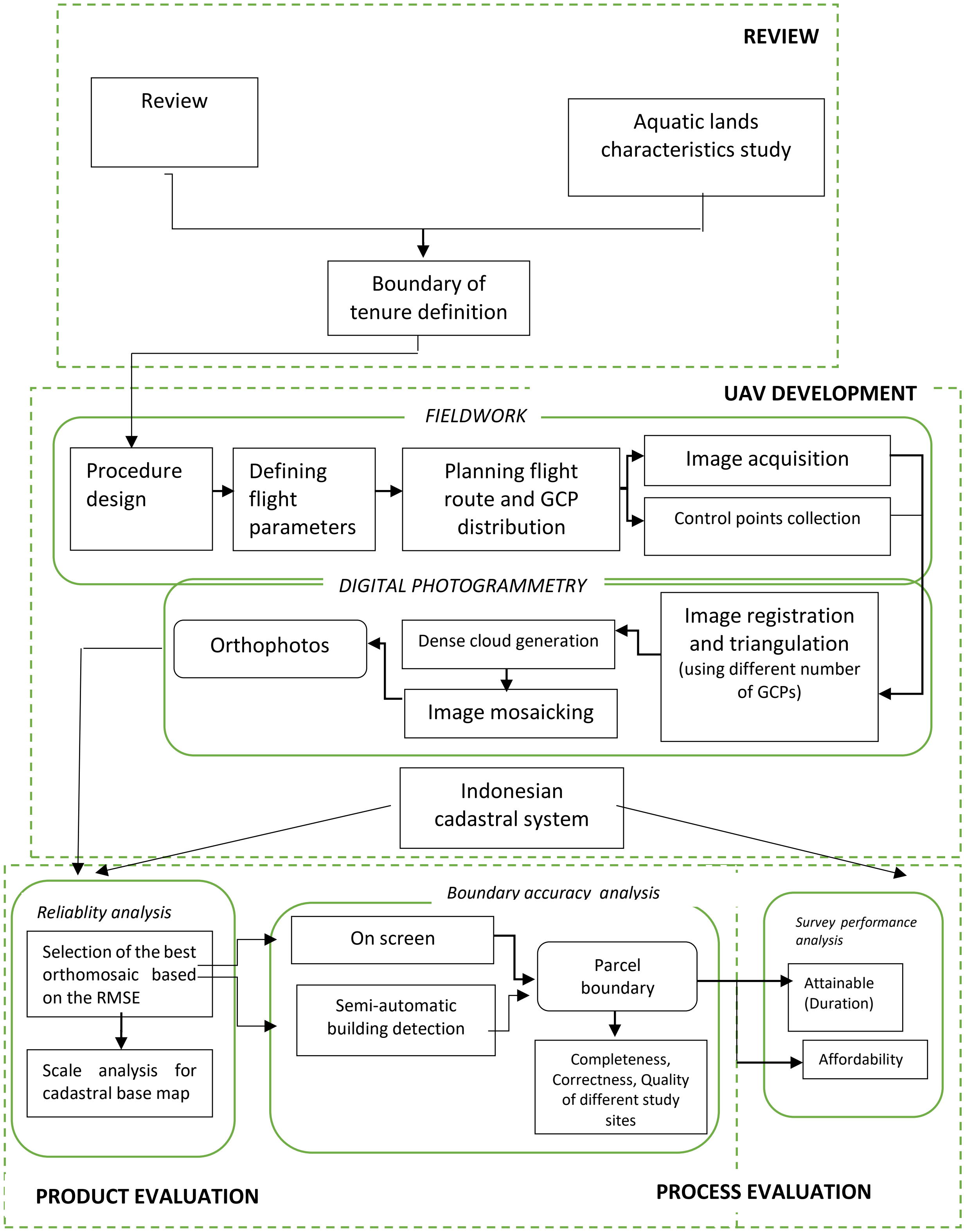


Figure 38. Workflow for assessing UAV-based cadastral survey in boundary acquistion

Table 30. Specifications of the plane

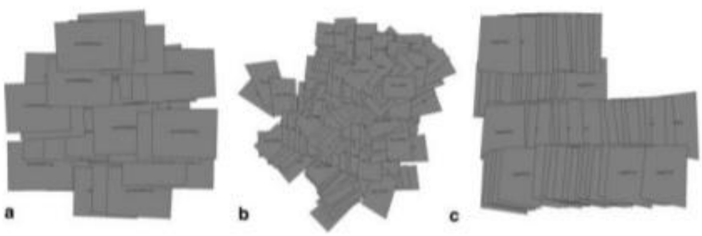
Specifications	
Airframe Body Type	EPO With carbon structure
Servo	4: 2 servo aileron, 1 servo elevator, and 1 servo rudder
Finishing	Coating and coloring
Battery	5500 MaH
Duration	35-40 minutes (depends on wind speed, optional 120 minutes long-range mode)
Flight range	Up to 40 Km (optional 80 Km long-range mode)
Wingspan	1880 mm
Take off	Hand launch
Power	Electric
Altitude	Up to 3000 m
Telemetry range	Up to 15 km (optional 30 km, 28 km tested), frekuensi 915 MHz
Wide area on 400 m AGL	Up to 200 ha (optional 1000 ha on long-range mode)
Waypoint	Unlimited
Weight	3-4 kg
Easy handling	Provide with hardcase
Camera	Sony QX10 18 Mpixel

Figure 39 The camera and fixed-wing vehicle used in this study

4.2.2 Flight planning

The coordination with the authority (Riau Islands Land Offices and Village Office) was established before the flight. In every UAV survey, flight planning generally considers the size and shape of the area of interest (AOI). Thus, with regard to efficiency, aircraft ability, and ground conditions, some parameters were established as follows:

1. Flight pattern. In practice, there are three types of flight patterns: manual mode, irregular image overlap, and automated flying and acquisition mode (Figure 40). The latter is usually taken for survey and mapping purposes, as it is more systematic in reducing errors and uncertainty than the others.



a) manual mode, b) irregular image overlap, and c) automated flying and acquisition mode

Figure 40. Different flight patterns, source: (Nex and Remondino, 2013)

We created a regular automated pattern using Mission Planner software, and we set the flight route linearly to gain consistent overlaps. The flight height was set at +-300 m above the ground (see Figure 41).

2. Ground Sample Distance (GSD) target. In a flight plan, GSD is determined to understand the size of one pixel on the image and how that corresponds to a set measurement on the ground. In literature, GSD is defined as the distance between two consecutive pixel centers measured

on the ground. In practice, it is simply the size of the pixel in the field (Federman et al., 2017). GSD also points to spatial resolution and usually is represented in the metric system (cm or m). The smaller the GSD value, the better the spatial resolution. The target GSD is 8-10 cm, but later the real GSD would be calculated by the processing software Agisoft Photoscan Professional using the formula:

$$\text{GSD} = \frac{Sensor\ height\ (mm)\ \boldsymbol{x}\ flight\ height\ (m)\ \boldsymbol{x}\ 100}{Focal\ lenght\ (mm)\ \boldsymbol{x}\ image\ height\ (pixel)} \quad \text{(eq. 27)}$$

3. Overlap and sidelap.
   While overlap (also called forward lap) denotes the amount by which one image includes the area covered by another image in the same flight line, sidelap points the amount of overlap between images from adjacent flight lines. To optimize the tie points and prevent gaps due to crab, tilt, flying height variations, and terrain variations, the sidelap was set to 70%, and overlap was set to 75%. This number is fulfilling the requirement for UAV mapping in Indonesia as stipulated in Guideline No. 2 of 2017 from ATRBPN about working map creation using drones, which is >60 for sidelap and >70% for overlap/forward overlap.

Figure 41. Flight planning

   Because the land-area in the north and south side is separated by water with a distance from 500 m to 1 km, as a precaution, one strip was added across the AOI, from the northwest to southwest.

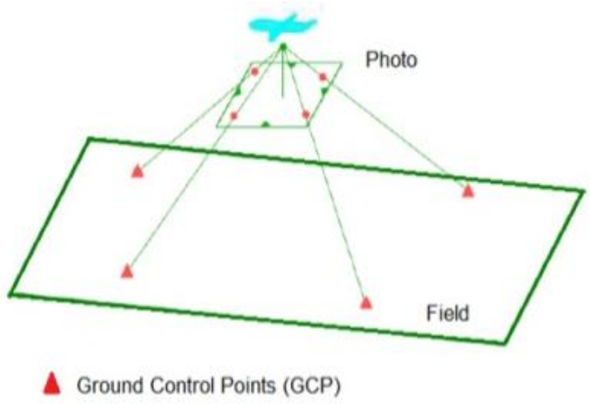
4. Photo recording
   Two common techniques for recording images are time and distance recording. The first is relatively easy, as the setup will only use camera time without the necessity of arranging autopilot mode. Unfortunately, this is not relevant for coastal areas where wind speed is not stable, causing inconsistency in planned overlap and sidelap. Therefore, we used auto shutter by distance. The camera will automatically shoot at a certain distance. On this flight, the camera recorded every 78 meters.

Based on those parameters, the total flight distance would be 63 km. The flight duration was 1 hour 40 minutes with a 12 m/s average speed.

4.2.3 Control and Checking Points

In general, recent UAV systems and cameras have positional tools. Most UAVs use the tool only for navigation. Errors arising from surface conditions, lighting conditions, and image network geometry (Jaud et al., 2018) prevent the produced photos from being optimally georeferenced using that navigation tools alone, rendering them unreliable for detailed mapping purposes. Increasing positional accuracy can be proceeded with directly and indirectly (Yildiz and Oturanc, 2014). Direct georeferencing means integrating a more reliable positional tool such as Real-time Kinematic or Post-Processing Kinematic Global Positional System (GPS) and the Inertial Measurement Unit (IMU) sensor on the plane. This GPS/IMU system will directly measure the exterior orientation parameters (camera position and rotation) for determining the georeferenced position of the image. In the indirect georeferencing technique, instead of adding onboard tools, the exterior orientation process that determines camera position in the object (ground) coordinate system is approached by some ground control points (GCPs).

GCPs are the points whose positions (x,y,z) are known accurately in a ground coordinate system and can be positively identified in the photographs. They are used for georeferencing products by rotating, scaling, and orienting the images to a real-world location of interest for digital reconstruction in a post-processing process, usually done by Bundle Block Adjustment (Yildiz and Oturanc, 2014). The UAV survey in this study used GCPs to increase the accuracy (see Figure 42).



Indirect georeferencing technique (Source: Yildiz and Oturanc, 2014)

GNSS measurement of the GCP on the premark (Source: Author).

Figure 42. Indirect georeferencing technique and premarks

GCPs were established as Premarks. The premark is a marking or painting certain figures or symbols that have color contrast with the ground. It was made in size 50 cm x 150 cm and placed prior to the flight so they would be recorded in the images. Besides the GCPs, we also used Independent Check Points (ICPs). These points would not be used for geometry correction but for testing the positional accuracy of the orthophotos. The ICPs take Postmarks or Photo-Identifiable (Photo ID) marks. This mark could be any existing and identifiable feature on the ground, such as a building corner, road or bridge junction, fence stick, parking stripe, etc. The marks were surveyed after the UAV flight.

In UAV surveys, the ideal required number of GCPs might vary (Sanz-Ablanedo, Chandler, Rodríguez-Pérez, and Ordóñez, 2018). However, a minimum of three points is required (James and Robson, 2012). The investigation from Prajwal et al. (2016) revealed that three GCPs are sufficient to produce desired accuracy for a given stretch of 600 meters. In other research, it was found that increasing the number of GCPs will lead to higher accuracy (Tonkin and Midgley, 2016; Oniga et al., 2018). Tahar (2015) found that by using 7 GCPs or more, the error starts decreasing. According to James and Robson, the important consideration is that the GCPs are located on placed where can be positively identified on the photos, measured accurately and be distributed homogeneously. The

GCPs also should be near the perimeter of the AOI to cover the whole extent of the area (Javernick et al., 2014; Smith et al., 2015).

In Indonesia, for creating a cadastral base map, while using Orde 3 control points, ideally the GCPs should be located no more than 2000 m from each other (BSN, 2002) and the ICPs are distributed in between those GCPs. The spatial extent limitation and inaccessibility (the appearance of the water area, private properties) and GNSS satellite masking (vegetation cover, building, etc.) make the placement and configuration of the points (especially the GCPs) can not be ideal. By still following the recommendation from BSN, we then used 15 points, consisting of 8 GCPs and 7 ICPs (Figure 43). In this thesis, we used and investigated different numbers and distributions of GCPs to build the orthomosaic. This thesis used 4, 5, 6, 7, and 8 GCPs, and then based on the errors, we chose the most reliable one for extracting the boundary.

We deployed GNSS Geodetic measurement with the differential static approach, which means the GNSS units were steadily mounted in the Premarks and Photo IDs. A base and a rover unit operated simultaneously in order to have the rover points get corrected later in the post-processing using the software. The coordinates in base points were corrected by input from Post-Processing Service Based on RTX Technology from Trimble, and the coordinates in rover points were corrected from the base points' (using radial technique processing). For the GCPs, 4 points will become the base, and another 4 points will be the rover. One rover would get the correction from one base. For ICPs, all points were a rover, which were post-corrected from a base point that functions as a benchmark. A field situation was sketched to help identify the markers in the orthophotos. GCPs and ICPs measurement results can be seen in Appendix 6.

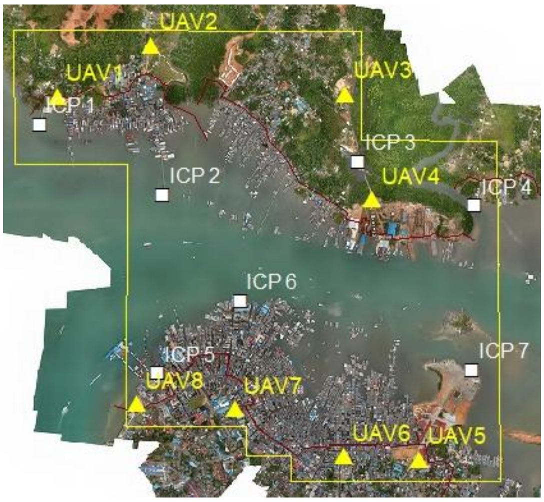


Figure 43. Distribution of the GCPs and ICPs

4.2.4 UAV image data processing

After capturing images from the flight and acquiring the GCPs and ICPs, the next step was processing those images to produce orthophotos or orthomosaics as the surface model. This step is known as digital photogrammetry. Being in the ortho level means the relief displacement has been orthorectified using height models to make the entire photo orthogonal and then assumed the photo would deliver a uniform scale and the distance measurements are the same across it. As many photos were stitched for being a mosaic that covers the project area, they are also called orthomosaic. To reconstruct the model, we used Structure from Motion (SfM) Photogrammetry, a computer vision technique, for this process. As SfM is also combined with Multi-View Stereo (MVS) technique, some literature call this SfM-MVS (Smith et al., 2015, Jaud et al., 2018). Agisoft Photoscan Professional was used as the processing software.

Turner et al. (2016) define SfM as a photogrammetric technique that derives 3D information (dense point clouds) to build 3D surface reconstructions from a series of unordered overlapping 2D photographs and control points. A key understanding of this technique is that it requires many images of an area or an object with a high degree of overlap. The images are taken from a moving platform with different angles to make the automatic feature-mapping algorithms work properly in the overlap area by determining as many points of matching objects and textural features as point clouds (Micheletti et al., 2015).

Both SfM photogrammetry and traditional photogrammetry use the same stereoscopic photogrammetry principles (i.e., using triangulation to calculate the relative 3D positions of objects from stereo pairs). However, while conventional stereo photogrammetry is strict in steady images and camera calibration, UAV-SfM relies on the 3D point clouds that can be generated in image-space coordinates, which enables the unstructured images from many angles and distances or even without a prior location to be used, and the internal camera can be determined without prior calibration (Jaud et al., 2018). It makes this technique does not need a specific photogrammetry camera; a budget and consumer camera is adequate. Although later, indeed, a set of GCPs might be required for creating accurate georeferenced photos.

The steps of SfM technique could be slightly different among software, but in general, the main steps are (1) image orientation (2) creation of dense points (3) elevation model computations and orthomosaics generation (Jaud et al., 2018). Image orientation consists of image matching, tie point extraction, estimation of camera external and internal orientation, and refinement of external orientation and self-calibration. Dense point creation is the dense matching using the estimated internal and external orientation. Elevation model is usually in DEM format, which is created by rasterizing the dense point cloud data on a regular grid. Based on DEM, the orthomosaic then created. In the Agisoft (Agisoft, 2016), following the procedure by Jaud et al., the process of SfM can be depicted as follows:

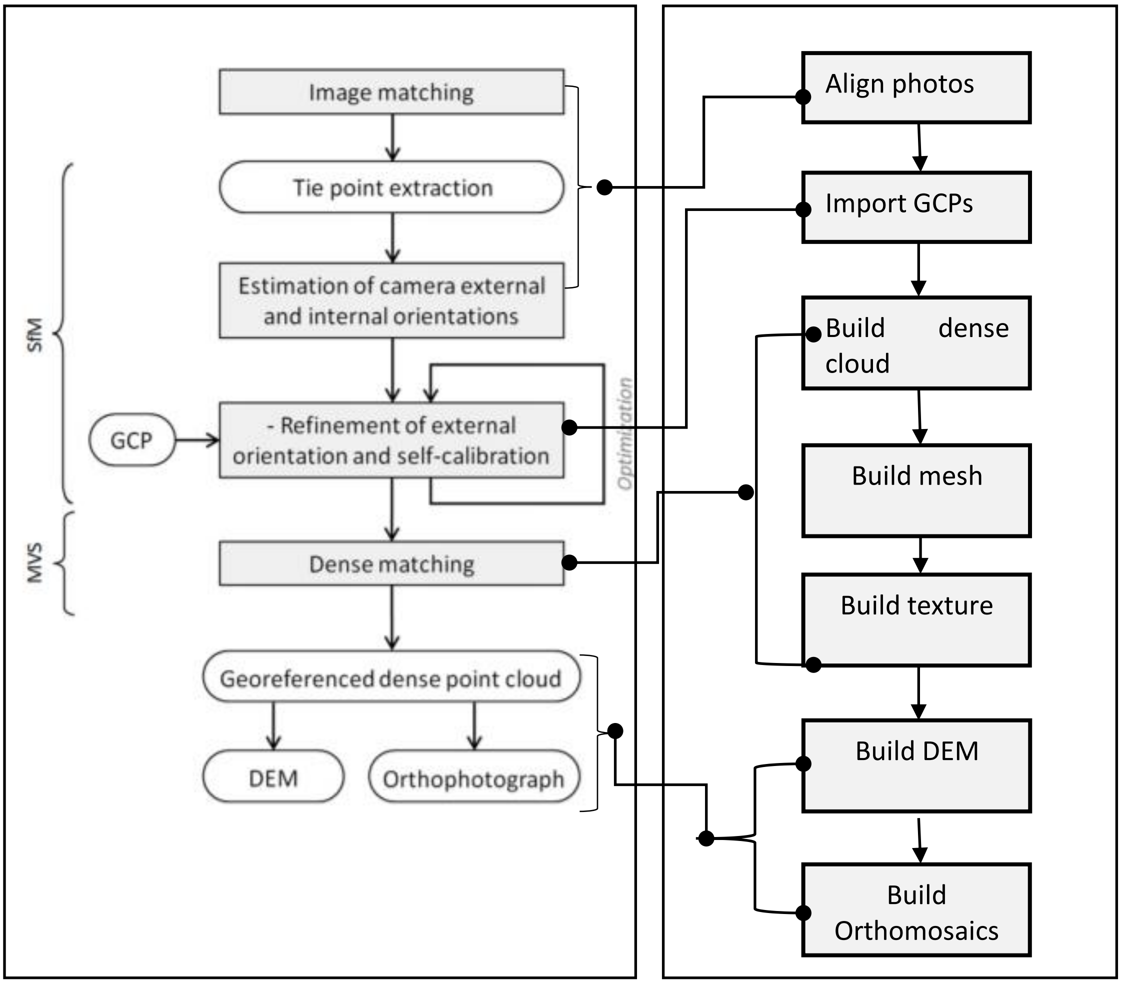


Figure 44. Workflows from Jaud et al. (2018) (left) and from Agisoft Photoscan (right)

Below are the steps taken by this research for conducting SfM following the workflow from the software (Figure 44, right side):

1. Align photos.

This 1st step is initially by sorting the photos based on quality and necessity. Too obliged or blurred photos were eliminated. The photos located in the area far outside the AOI were excluded. Total photos from the flight are 686, but after elimination, only 576 were used.

After selecting the photographs, the first step in the model generation process is to align the photos. Align Photos stage aims to set the camera positions and orientate the images in order to create a point cloud model from the same objects. The photos in high accuracy version (original size) were first analyzed by the software to find homologous points on the overlapping photos using a Scale-Invariant Feature Transform (SIFT) (Jaud el al., 2018). These feature points were defined based on the pixel value of the objects and their surroundings. Then a matching process using *generic* pair preselection mode was done to match these feature points among images to find corresponding feature points. We set the limit of *key points* (detectable points) and *tie points* (matching points) to 700.000 to obtain more representative points. The other activity in this stage was a bundle adjustment procedure to compute the camera's external orientation and tie point coordinates based on collinearity equations. The result of Align Photo stage is a sparse 3D point cloud and modeled camera self-calibrations and positions.

2. Import GCPs.
For conducting better image triangulation and registration or for refining the self-calibration and external orientation of the images a GCPs dataset was used. We imported the points in .txt format. The GCPs positions as the ground markers needed to be defined and placed properly according to their positions in the images by means of the premark sign. Then, a camera alignment optimization was conducted to reconstruct the photos based on the defined GCPs and to improve the geometric quality of the photos (for example, correcting the "bowl effect").

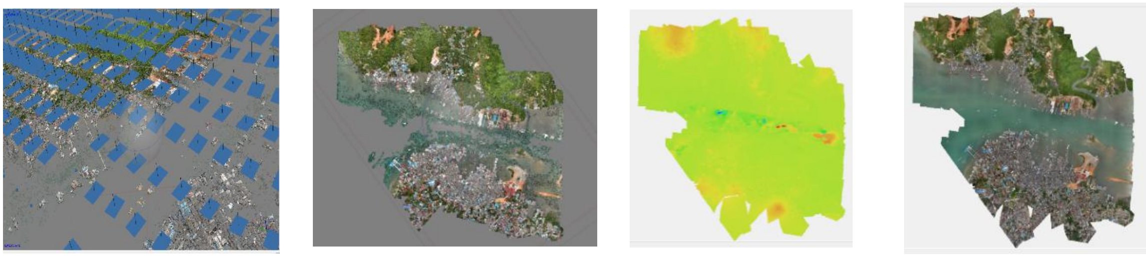
3. Build dense cloud
Using the known camera parameters and the sparse cloud points, the dense cloud points were made. This step is known as Multiview Stereo Matching (MVS). Two important parameters in this step are *quality* and *depth filtering mode*. *Quality* sets the level of photos used for reconstructing the dense points. *Depth filtering mode* specifies how the software deals with outlier points when calculating depth. We chose *High* quality photos (photos are downsampled by the additional factor 4) and *Mild* filtering mode (small details are important to the model).

4. Build Mesh.
Using the dense cloud as the source, Mesh had been created to represent the surface. This 3D model functions as the foundation to build DEM and the orthomosaic. To avoid very long-duration processing and because the topography of the area is flat, Height Field surface type was chosen where the surface would be interpolated completely to avoid holes in the model (Extrapolated mode).

5. Build Texture.
Texture is the color overlay of the point cloud. Texture creation is mandatory as the orthomosaic would require texture in the making process. In this work, the texture was generated using *Orthophoto* mapping mode (best for horizontal area; the texture is not calculated in the elevation orientation). The blending mode took *Mosaic* mode, which works by blending specific pixels from the best photos with pixels from other images to avoid seams in the texture.

6. Build DEM.
To create orthogonal images, we need DEM. The source of DEM is the dense cloud, and DEM is only possible if the GCPs are used.

7. Build orthomosaic.
In building the orthomosaic, the surface source for texture overlay is DEM (Figure 45 part c). Compared to *Mesh*, DEM is better for aerial survey data or georeferenced data (Shervais et al., 2016). The used blending mode is *mosaic*.



(a) Aligned photos | (b) Point cloud (dense) | (c) DEM | (d) Orthomosaic

Figure 45. Processing results

4.2.5 Boundary extraction

After acquiring the orthomosaic, the subsequent procedure involves generating a border overlay on the resulting image (the flowchart is shown by Figure 47). As previously mentioned in Section 4.1.3, we will use building footprints as the boundaries. To generate building footprints, two distinct methods can be employed: on-screen delineation/digitization and extraction methods. In the first method, generating boundaries is done manually, typically facilitated by the utilization of Geographic Information System (GIS) software. Images with very high spatial resolution (within a range or less than 10 cm), like UAV orthophotos, have the potential to yield accurate delineation of building boundaries. The building objects are distinguished from surrounding objects, such as soil, water, roads, vegetation, etc., because of their clear visualization boundaries. They may be easily interpreted based on elements of shape, pattern, color, texture, size, and site.

The second technique, known as the extraction method, is commonly referred to as building footprint extraction and falls under the domain of feature extraction. It is also sometimes abbreviated as building extraction (Khatriker and Kumar, 2018) or rooftop mapping (Brooks et al. 2015). There exist two distinct categories of this approach: pixel-based and object-based. A pixel-based approach allows us to classify and isolate the only objects we are interested in, for example, buildings, roads, etc., which are challenging and lack robustness due to the complexity of structure and design in urban environments. The object-based approach classifies imagery based on the identification of objects (also called segments). These segments are defined as clusters of pixels or regions of interest that exhibit comparable spectral, spatial, and/or textural characteristics that define the region. According to Myint et al. (2011), research findings indicate that object-based classification outperforms pixel-based classification in the identification of urban land cover classes using multispectral images. With high-resolution panchromatic or multispectral imagery, an object-based method offers more flexibility in the types of features to extract.

This extraction method is based on analysis by certain algorithms of spatial, spectral, and texture characteristics (Gavankar and Gosh, 2018). Urban areas are dominated by built-up features such as buildings. The spatial and spectral properties are the two important factors for extraction. Spatial properties deal with space and how the combination of neighborhood pixels is defined by the location of those pixels. Spectral properties deal with the unique spectral signatures of features and behaviors of objects in different ranges of band values in multispectral imagery.

Two prevalent methodologies for building extraction include automatic and semi-automatic approaches. Automatic feature extraction techniques typically employ various morphological operators. For instance, Jumlesha et al. (2012) utilized mathematical operators to extract urban features, including roads and buildings, from satellite imagery within a Matlab environment. Similarly, Benediktsson, Pesaresi, and Arnason (2003) proposed an urban area classification method that combines morphological operators with neural networks; the morphological operators are applied to extract features, while neural networks are used to classify these extracted features.

The process of automatic extraction of buildings from satellite images has always been a difficult task and has long been recognized as a challenging endeavor due to various factors. These factors include the variability in building structures and shapes, as well as the presence of impediments presented by nearby objects like trees and high-rise buildings. Furthermore, the contrast between the roof of the building and the surrounding region may be low, which has been an important criteria in segmentation, and varying roof material reveals different spectral characteristics. Building tops in urban areas usually do not have similar shapes, sizes, and textures. Nevertheless, these buildings still have certain common characteristics, such as their bright appearance and high contrast to the surrounding features, that make, in this thesis, a semi-automatic strategy was adopted, which is typically accomplished by picture segmentation based on user-specified criteria and classification of the segmented image to extract the desired characteristics. The process of splitting an image into segments with similar spectral, spatial, and/or textural features is known as segmentation. The segmentation process involves segmenting a picture into pixel sections, computing characteristics for each region to generate objects, and then categorizing the objects (using rule-based or supervised classification) based on those attributes to extract features.

On the other side, there is also a semi-automatic approach, where a set of rules is devised to distinguish buildings from other objects within images (Agustina, 2019). The formulation of these rules, initiated during the segmentation process, significantly impacts the efficacy of building extraction. Moreover, the accuracy of detailed semi-automatic building extraction results is contingent upon data possessing high spatial resolution (Agustina, 2019). This method, employing object-based classification techniques with high-resolution imagery obtained from UAVs, offers several advantages such as cost-effectiveness and the ability to swiftly generate highly accurate data (Selim et al., 2019).

The semi-automatic approach demonstrates notable precision in extracting buildings from high-resolution satellite imagery, for example, through a combination of snake models and radial casting algorithms for effective extraction (Mayungaa et al., 2005). It proves applicable for excavating both structured and unstructured buildings (Mayungaa et al., 2005). This approach offers several benefits. It works well for different building types, regardless of their shape or size. It also reduces image noise and quickly extracts buildings from high-resolution images (Jiang et al., 2008). In general, the semi-automatic method facilitates rapid processing with minimal manual intervention.

UAV technology combined with GIS software has proven to be efficient in object detection. GIS software allows the incorporation of tools for visualization, manipulation, analysis, and processing of geographic data obtained from UAVs. GIS software, especially open source ones like QuantumGIS (QGIS), provides flexibility in developing new plugins to automate procedures and integrate various external algorithms, including image processing algorithms. Using QGIS or similar GIS software, users can integrate powerful image processing algorithms to support the analysis of objects in UAV images (Duarte et al., 2018). Additionally, to assess the accuracy of the extracted building footprint, ArcMap software can be employed to compare it with a referenced data (Dai et al., 2017).

Once building footprints are acquired, the accuracy can be evaluated by comparing the digitized building footprint with the extracted building footprint. In this research, we have tried two different techniques to extract buildings from the imagery. The first one is an object-based image analysis (OBIA) technique with ArcMap as processing software and the second is Mapflow.ai in QGIS. The main difference between these two is the former needs some steps to produce building footprints while the latter is more automated process.

Building extraction can be done semi-automatically in OBIA. It will group pixels with similar characteristics into segments of a single object by considering spatial, spectral, and textural information to produce good classification and detection of objects (Selim et al., 2019). The segmentation is divided into three main steps, following Sadhasivam et al., (2020) and Priyadarshini et al, 2020).

1) Segmentation.
   The basic procedure in segmentation involves breaking down images into objects that represent land-based features. This step is the process of grouping pixels from data into shaped objects based on compactness and shape arrangements. In ArcMap software, we used a tool called Segment Mean Shift to run this step. In the hope of gaining maximum display of building footprint, we have set the Spectral Detail and Spatial Detail menu in the tool to the highest allowed value, which is 20.
2) Classification.
   Once the image is segmented into objects, the next step is to classify the objects into features by using defined class rules. This classification of objects can be done because each object has different statistics, such as geometry, color, etc., associated with it. We need to create a training set based on color difference of the object as class rule. Through the training set, we can perform object classification using Support Vector Machine (SVM) technique which is capable

of determining feature spaces that enhance classification performance (Chutia et al., 2014). In ArcMap software, SVM can be executed with the Train Support Vector Machine Classifier tool. Because there is no absolute way to classify land cover features using OBIA, the process of trial and error is often used to define the characteristics of objects that are optimal for classification.

3) Extraction.
Once objects are classified, building footprints can be extracted. This is done by selecting a class containing the building footprint. Once object extraction is complete, the resulting layer can be exported as a vector file. It allows spatial representation of channel networks in the form of vector files that can be used in a variety of GIS applications.

After using OBIA, this research also extracted the building fooprints using Mapflow.ai in QGIS. Mapflow.ai utilizes a deep learning technique known as Mask R-CNN for building detection through combination of object detection and instance segmentation. Mapflow.ai utilizes a trained Mask R-CNN model on a large dataset of satellite images and building annotations. Through training, it learns to distinguish buildings from other elements, attempting to accurately detect buildings in the images or aerial photos (Pindarwati and Wijayanto, 2023). The tool then autonomously produces vector roof outlines in the form of polygons (Hristov et al., 2023).

Because it relies on pre-trained Artificial Intelligence (AI) for building extraction, Mapflow.AI tends to be straightforward. Aerial photo data to be processed can be directly inputted into QGIS, and users can activate the installed Mapflow.AI plugin. Users need to configure Mapflow.AI to utilize the planned orthophoto as the data source and to extract only buildings, that configuration is done simply through the available menu options. Once the configuration is complete, the orthophoto can be uploaded to the Mapflow.AI server for processing.

The building extraction process in Mapflow.AI was carried out using deep learning techniques, specifically Mask R-CNN (Mask Region-based Convolutional Neural Network). The deep learning techniques presents a powerful approach for automatic extraction of buildings (Luo et al., 2021). Mask R-CNN generates region of interest (RoI) after Faster R-CNN, then applies a mask branch called FCN to each RoI, predicting segmentation masks pixel by pixel. It is a flexible framework used for various tasks with state-of-the-art performance. Mask R-CNN performs detection first, then segmentation, identifying objects with bounding boxes and segmenting them into specific regions (He et al., 2017; Chen et al., 2020). The building extraction process takes 15-30 minutes depending on the total area of all buildings. Once the building extraction process on the Mapflow.AI server is complete, users can download the extracted building data in Shapefile format for visualization through QGIS.

This method has the capability to perform object-level segmentation effectively, yet the extracted building footprints still require post-processing for improved structural coherence (Bimanjaya et al., 2021). As in this research we use a semi automatic approach, manual adjustment is applied in building results from OBIA-based and Mapflow.AI-based. The adjustment is made by removing small polygons that are considered to represent other objects in the image (such as boats/roads/others) and conducting building generalization through generalization tools.

Before conducting the boundary extraction, the first step we carried out on the orthophoto was conducting a feasibility analysis. The analysis observed irregularity, density, and distance between buildings. In general, we found three types of housing pattern:

1) Irregular (both shape and size), very dense, huddled buildings.
2) The buildings are fairly organized and not overly crowded, with gaps remaining between them. They can still be clearly visually distinguished from one another.
3) Despite their dense organization and close proximity, the buildings are still quite different from one another, allowing them to be distinguished.

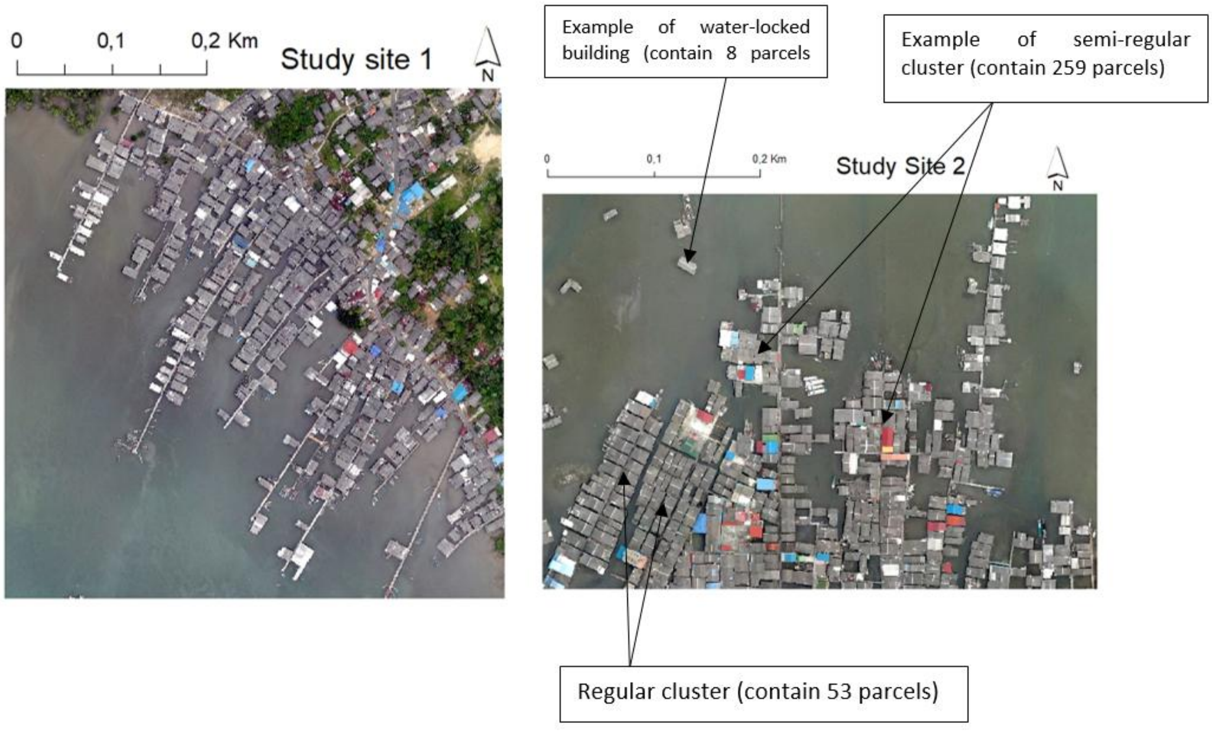


Figure 46. Study sites

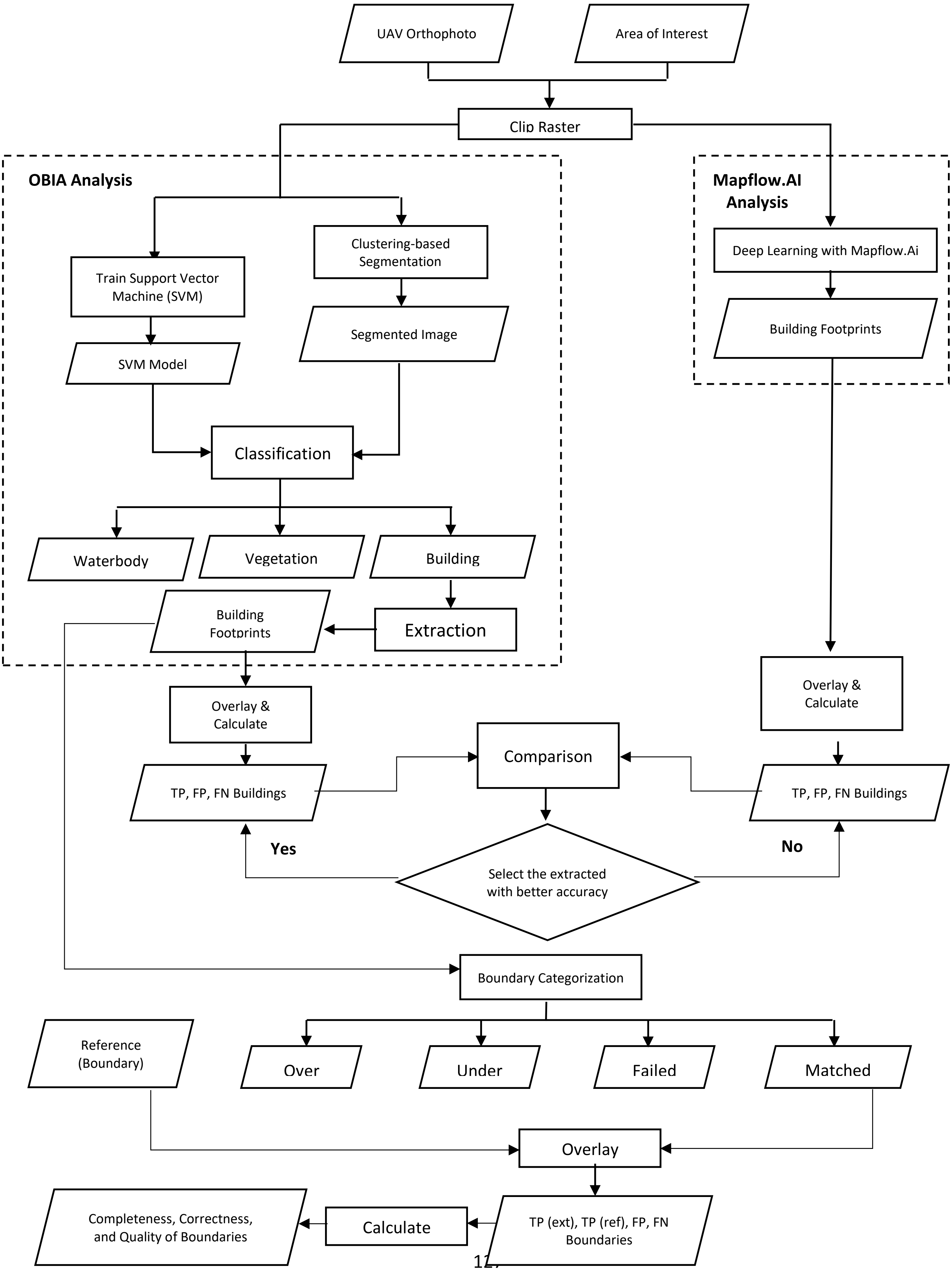

UAV Orthophoto
Area of Interest
Clip Raster
OBIA Analysis
Mapflow.AI Analysis
Clustering-based Segmentation
Train Support Vector Machine (SVM)
Segmented Image
SVM Model
Classification
Waterbody
Vegetation
Building
Building Footprints
Extraction
Deep Learning with Mapflow.Ai
Building Footprints
Overlay & Calculate
Overlay & Calculate
Comparison
TP, FP, FN Buildings
TP, FP, FN Buildings
Yes
No
Select the extracted with better accuracy
Boundary Categorization
Reference (Boundary)
Over
Under
Failed
Matched
Overlay
Completeness, Correctness, and Quality of Boundaries
Calculate
TP (ext), TP (ref), FP, FN Boundaries

Figure 47. Flowchart of building and boundary extraction and validation process

Because some areas had irregular building patterns, the orthophoto could not clearly show building boundaries. This made it impossible to accurately extract boundaries in these areas. Therefore, we excluded these areas from our study. We only focused on areas with more regular building patterns, specifically types 2 and 3. Two orthophoto subsets, Study Site 1 and Study Site 2, were selected as evaluation sites for boundary generation (see Figure 46). Both sites were chosen purposively. Both reflect conditions in points 2 and 3. Study Site 1 is located in the northern part of the orthomosaic and Study Site 2 is in the southern part. Both sites have different characteristics. Study Site 1 is more homogeneous with regard to the rooftop color of the building, the shape of the building, and the distance between buildings. The housing pattern in this site is mostly semi-regular (there are patterns, but not uniform). Study site 2 is more heterogeneous; there are regular parts of distance, size, and there are housing clusters whose patterns are not uniform at all, and even, some houses are water-locked buildings. Analyzing these clusters will show us in which areas segmentation methods yield the best results.

4.2.6 Result

Result from both technique in Site 1 and Site 2 can be be seen in Figure 48.

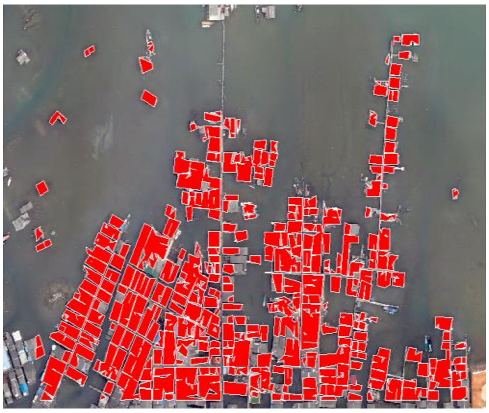
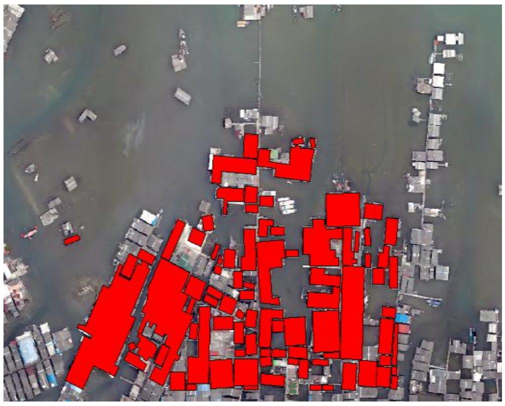
Site	**OBIA**	**Mapflow.AI**
Site 1		
Site 2		

Figure 48. Building extraction result

At a glance, we can see that building footprints derived using OBIA analysis generate a more representative extraction than those derived using Mapflow.AI. Mapflow.AI is unable to extract certain buildings, especially those located further away from the coastline. This phenomenon may occur due to the roof's similar color to the seawater, which prevents Mapflow.AI from identifying it as a building. In Site 2, where building density is higher, Mapflow.AI sometimes treats multiple buildings as a single building and extracts them accordingly.

Upon closer inspection, results from both techniques showed weaknesses. OBIA produced building boundaries with jagged edges, not straight lines (see Figure 49). We tried to simplify it with the automatic generalization tool in ArcMap, but due to asymmetrical features of buildings, the tool did not improve the boundaries completely. The generalization required manual intervention to smooth the edges of the extracted buildings.

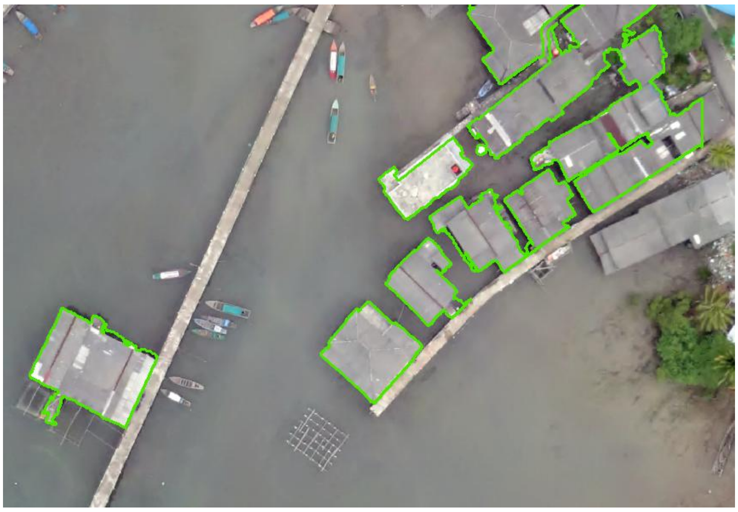


Figure 49. Building Footprint From OBIA Analysis

While it is not spiky-shaped and looks cleaner, building footprints from Mapflow.AI also have their flaws. Buildings (or building roofs) with simple square shapes can be extracted fairly well, but when facing more complex roof shapes, it gets worse (see Figure 50). Errors in building extraction can vary from minor differences in the outline to significant issues such as misplaced boundaries, merged buildings boundaries, or rotated boundaries.

Figure 50. Building Footprint From Mapflow.AI

Mapflow.AI requires a large training set to operate optimally. Mapflow.AI seems to have a minimal training set for coastal or aquatic locations that leads to less ability to extract building objects accurately in those areas. In contrast, urban areas, Mapflow.AI struggled to identify roof colors similar to the color of seawater or other non-building objects. OBIA also needs a large training dataset for detailed building footprints. Unlike Mapflow. AI, in OBIA, we can customize the number of training sets ourselves; the advantage offers by OBIA. However, this also requires much trial and error, which will take more time.

4.3 EVALUATION RESULT OF UAV FIXED-WING TECHNOLOGY

4.3.1 UAV products reliability

4.3.1.1 Image accuracy

RMSE and CE90 values determine the accuracy of orthophotos as cadastral base maps. RMSE measures how much error there is between two data sets. In other words, it compares a predicted value and an observed or known value. CE90 is defined as the horizontal position accuracy value with a confidence level of 90%. The value of RMSe (Root Mean Square Error) of the ICPs is measured using equation 29 and 30.

$$RMSE(xy)\ per\ ICP = \sqrt{RMSEx^2 + RMSEy^2} \qquad \text{(eq. 28)}$$

Where

$$RMSEx\ per\ ICP = \sqrt{\Sigma(Xgnss \quad - Ximage \quad)^2} \qquad \text{(eq. 29)}$$

$$RMSEy\ per\ ICP = \sqrt{\Sigma(Ygnss \quad - Yimage \quad)^2} \qquad \text{(eq. 30)}$$

And for RMSE of the image, presented by total error point, is total error in Ground Control (calculated as square root from the sum of squares and that’s all is divided by the number of GCPs)

$$RMSE(xy)\ total = \sqrt{\frac{\Sigma((Xgnss \quad - Ximage \quad)^2 + (Ygnss \quad - Yimage \quad)^2)}{n}} \qquad \text{(eq. 31)}$$

n = total number of point

Horizontal accuracy (CE90) = RMSE * 1,5175 (BIG, 2015) adopted from US NMAS (United State National Map Accuracy Standard) where: CE90 = 1,5175 x RMSEr

Note : RMSEr : Root Mean Square Error at x and y (horizontal).

To assess the effectiveness of the number and distribution of the GCPs, orthophoto models 1 to 5 were created using 4, 5, 6, 7, and 8 GCPs, respectively.

Figure 51 below shows the distribution of the GCPs within the models.

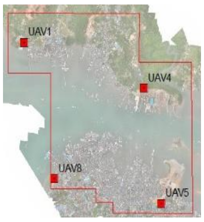
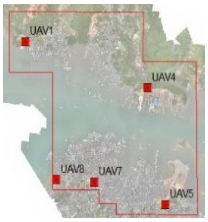
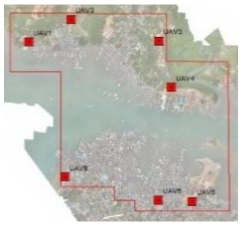
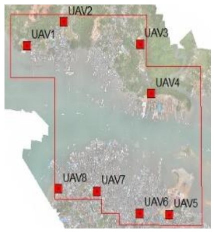
Ortho 1	Ortho 2	Ortho 3	Ortho 4	Ortho 5
4 GCPs	5 GCPs	6 GCPs	7 GCPs	8 GCPs
				
UAV 1, UAV 4, UAV 5, UAV 8	UAV 1, UAV 4, UAV 5, UAV 7, UAV 8	UAV 1, UAV 3, UAV 4, UAV 5, UAV 7, UAV 8	UAV 1, UAV 2, UAV 3, UAV 4, UAV 5, UAV 6, UAV 8	All (UAV 1 – UAV 8)

Figure 51. Different model using various GCPs number

From the orthophoto generation report (Appendix 7), for the five orthomosaic models that were made, an RMSE was obtained for each ICP. The whole RMSE of the ICPS in the models are presented in Table 31.

Table 31. RMSE report

	RMSE (xy)					
	Ortho 1 (4 GCP)	Ortho 2 (5 GCP)	Ortho 3 (6 GCP)	Ortho 4 (7 GCP)	Ortho 5 (8 GCP)	Average
ICP1	0,1068	0,1237	0,1707	0,1659	0,1670	0,1468
ICP2	0,1190	0,1811	0,2082	0,2066	0,2075	0,1845
ICP3	0,0871	0,0872	0,1259	0,1225	0,1226	0,1091
ICP4	0,3640	0,3957	0,2944	0,2936	0,2926	0,3281
ICP5	0,2421	0,2343	0,1878	0,1821	0,1833	0,2059
ICP6	0,3833	0,3469	0,2915	0,2958	0,2947	0,3225
ICP7	0,6968	0,6233	0,5907	0,5931	0,5916	0,6191
Orthomosaic	0,3499	0,3330	0,3034	0,3033	0,3029	

From this table, RMSE orthomosaic gives different results, and if displayed in graphical form becomes

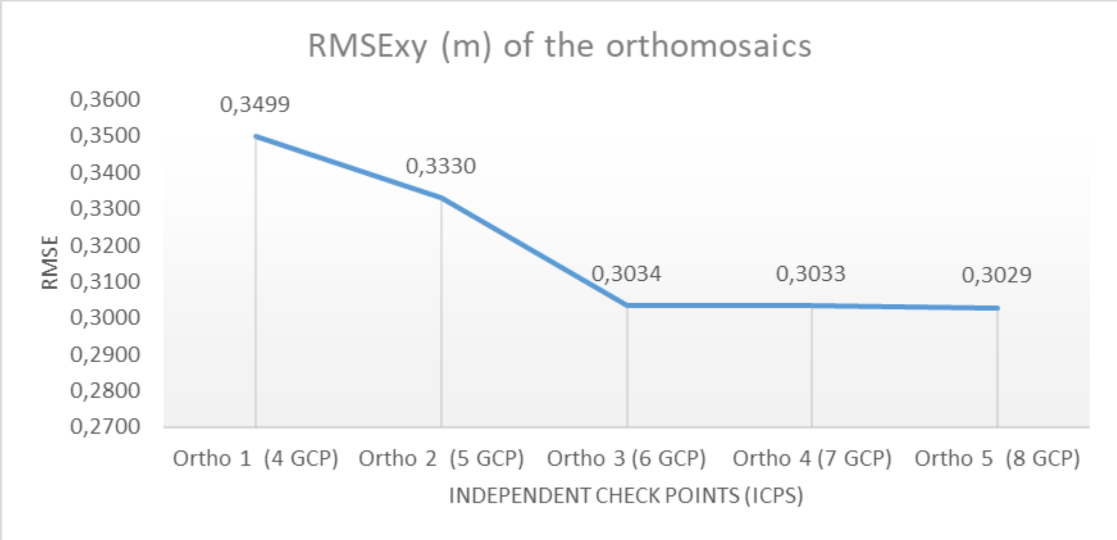


Figure 52. Graphics of RMSE

This graph of Figure 52 shows that Ortho 1, which only used 4 GCPs, has the largest RMSE. Conversely, the smallest RMSE is found in the orthomosaic generated with 8 GCPs. The trend line demonstrates that increasing the number of GCPs generally leads to a decrease in RMSE, indicating an improvement in the position of the resulting orthophoto. The addition of the fifth GCP resulted in the most significant reduction in RMSE, with a decrease of 0,0296 meters (2,96 centimeters). However, the addition of GCPs beyond 6 showed a diminishing return, with only a minor reduction in RMSE (0,0001 meters or 0,01 centimeters) between 6 and 7 GCPs, and 0,0004 meters (0,04 centimeters) between 6 and 8 GCPs. Considering time and cost efficiency, 6 GCPs appear to be an optimal number for this specific shooting project, as further increases in GCPs yield minimal improvements in accuracy. Nevertheless, for the subsequent steps of this thesis, Ortho 5, generated with 8 GCPs, will be utilized due to its lowest RMSE.

When viewed per ICP, the trend in RMSE reduction can be visualized in the graph below.

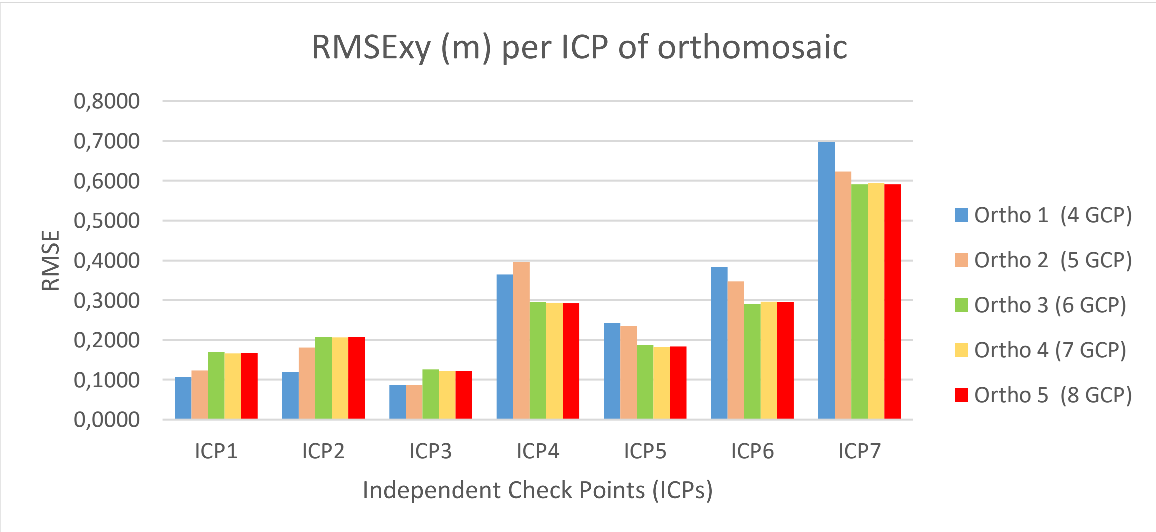


Figure 53. Bar chart of RMSE

From previous research results, as in classical photogrammetry, vertical errors in SfM will be 2,5 times the error of easting or northing components. Pixel4D, one of the SfM software, stated the expected error was 1-3 x GSD. But, if a few GCPs are used, as in this thesis, the RMSE in checkpoints will be about 5 times the averaged GSD of the project (Sanz-Ablanedo et al., 2018). The results of Agisoft's report show that the GSD obtained is 8,56 cm.

From the result, it can be known that
1. As shown in Figure 53, Ortho 5, which uses all GCPs and gives the smallest error, will be the used as the orthophoto model. The ICPs error in this model is presented in Table 32.
2. The smaller the error, the better the quality of the positional accuracy of the ICPs.
3. Table 32 indicates that ICP 4, 6, and 7 exhibit errors exceeding 3 GSD (~ 3 x 0,0858 m = 0,257 m). Assuming consistent accuracy across ICP measurements, the areas around these points likely have lower planimetric accuracy than the other areas.

Table 32. Error relative to GSD

ICP	Error (m)	Error relative to GSD
ICP 1	0,1670	1,9 x GSD
ICP 2	0,2075	2,4 x GSD
ICP 3	0,1226	1,4 x GSD
ICP 4	0,2926	3,4 x GSD
ICP 5	0,1833	2,1 x GSD
ICP 6	0,2947	3,4 x GSD
ICP 7	0,5916	6,9 x GSD
	Average relatif to GSD	3,1 x GSD

The table shows that there is a disparity of errors relative to GSD in the area of each ICP. Only one area, specifically the region around ICP 7, exhibits errors exceeding 5 GSD.

Based on Table 32 and an intuitive analysis considering the spatial distribution of ICPs relative to the GCPs (as visualized in Figure 54), it can be observed that:
1. The ICPs outside "the perimeter of GCPs" are ICP 4 and 7. They give a large RMSE. The result indicates that areas outside the GCP perimeter have lower accuracy.
2. Elevated RMSE values were observed at ICP 2 and 6, which are located relatively far from GCPs. Despite being within the GCP perimeter, these points exhibit significant errors, suggesting that accuracy tends to decrease with distance from the GCPs.
3. The ICPs near the GCPs, such as ICP 1, ICP 3, and ICP 5, have smaller RMSE than the others.

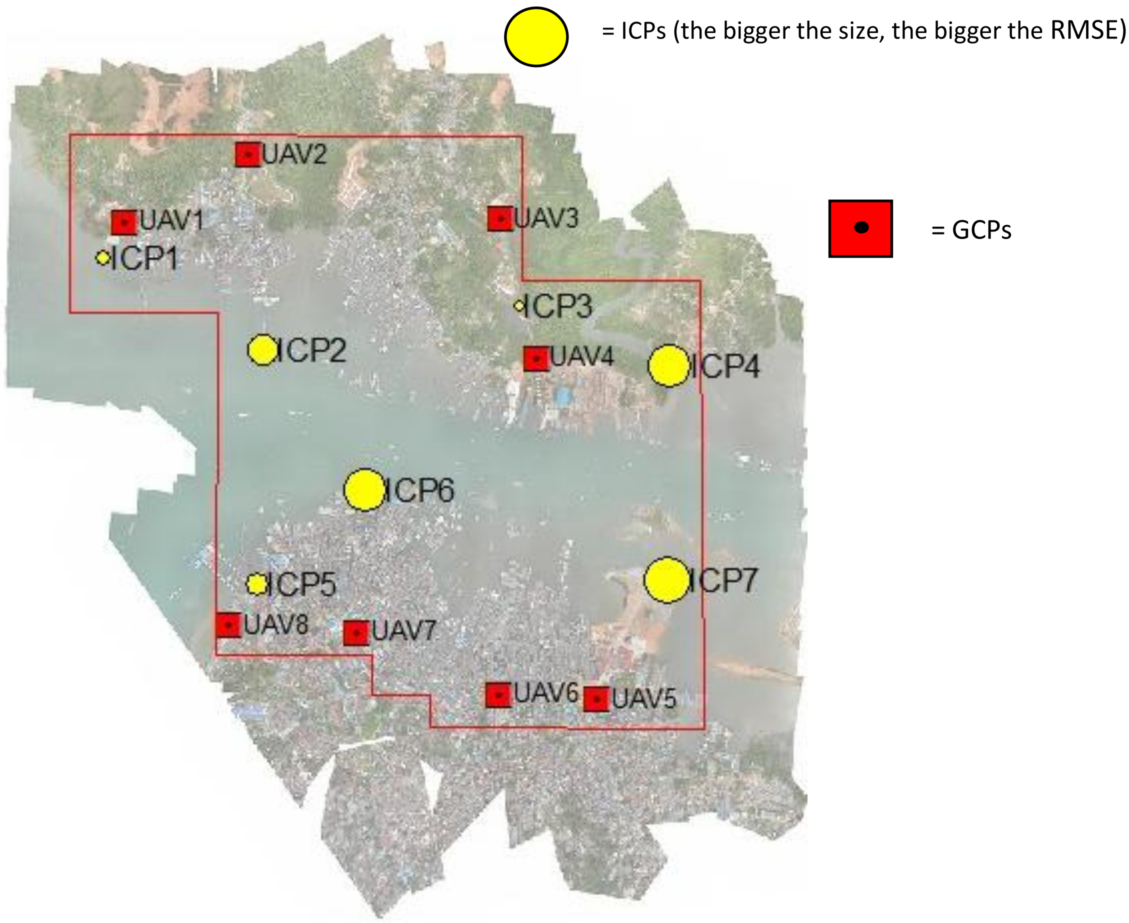


Figure 54. Distribution of GCPs and ICPs

Positional information for Ortho 5 is

- GSD : 8,58 cm
- RMSE (xy) : 0,3029 m
- CE90 : RMSE * 15,175 = 0,4596

Is the RMSE and CE90 value of the selected orthomosaic passing the standard for cadastral base maps in Indonesian context?

In mapping products, the inclusion of metadata for accuracy is crucial, serving as a form of quality control (BIG, 2014). To determine the appropriate scale for UAV orthophotos, an evaluation is conducted based on the standards set by Indonesian Geospatial Agency (BIG) and Ministry of ATR/BPN.

Standard from BIG

The regulation issued by BIG No. 15 of 2014, titled "Technical Guidelines for the Accuracy of the Base Map," classifies the horizontal geometric accuracy (CE90) required for base maps into three distinct classes with the following specifications:

Accuracy	Class 1	Class 2	Class 3
Horizontal	0,2 mm x scale factor	0,3 mm x scale factor	0,5 mm x scale factor
Vertical	0,5 x contour interval	1,5 x contour interval	2,5 x contour interval

Class 1 represents the highest level of accuracy, followed by Class 2 and Class 3. Only horizontal accuracy is analyzed in this study. Based on the following table, the required accuracy for any given scale can be determined accordingly (see Table 33).

Table 33. Indonesian Rupabumi Map (RBI Map) accuracy

No	Scales	RBI Map accuracy		
		Class 1	Class 2	Class 3
		CE90 (m)	CE90 (m)	CE90 (m)
1	1:1.000.000	200	300	500
2	1:500.000	100	150	250
3	1:250.000	50	75	125
4	1:100.000	20	30	50
5	1:50.000	10	15	25
6	1:25.000	5	7,5	12,5
7	1:10.000	2	3	5
8	1:5.000	1	1,5	2,5
9	1:2.500	0,5	0,75	1,25
10	1:1.000	0,2	0,3	0,5

The above table outlines the required accuracy for various map scales and accuracy classes. For instance, a map with a scale of 1:1.000.000 in Class 3 requires a CE90 of 500 meters, while a scale of 1:1.000 needs CE90 values of 0,2 meters for Class 1, 0,3 meters for Class 2, and 0,5 meters for Class 3. In this study, with an orthomosaic CE90 of 0,46 meters, the appropriate scales for the base map would be 1:1.000 for Class 3 and 1:2.500 for Class 1. This indicates that:

1. In the category of accuracy level Class 3, the orthophoto can be used as a base map with a scale of 1:1.000 because at least 90% of positional errors or shifts in the horizontal position of objects do not exceed 0,5 meters.
2. In the category of accuracy level Class 1, the orthophoto can be used as a base map with a scale of 1:2.500 because at least 90% of positional errors or shifts in the horizontal position of objects do not exceed 0,5 meters.

Standard from the Ministry of ATR/BPN and Standard from IAAO

According to Regulation of the State Minister of Agrarian Affairs/Head of the National Land Agency Number 3 on the Provision of Land Registration, there are three recommended categories for map scales based on land use characteristics:

a. For residential or urban areas, a scale of 1:1.000 or larger is recommended.
b. For agricultural and suburban areas, a scale of 1:2.500 is recommended.
c. For large plantations, a scale of 1:10.000 is recommended.

Recommendation from the International Association of Assessing Officers (IAAO) states that “commonly used mapping scales” are 1:1.200 for urban zones, 1:2.400 for suburb areas, and 1:4.800 and 1:9.600 for rural areas. (IAAO, 2016, p: 11).

The ATRBPN regulation specifies that the Root Mean Square Error (RMSE) should be calculated as:

RMSE = 0,3 mm x map scale

To determine the map scale produced by the orthophoto, the following formula is used:

Map scale = RMSE/0,3 mm = 0,3029 m/0,3 mm = 1.009,6.

So, the produced map is in the scale of 1:1.009 ~ 1:1.000

This indicates that the orthophoto can be used for large-scale mapping, as it meets the requirements outlined in the Regulation of the State Minister of Agrarian Affairs/Head of the National Land Agency Number 3 on Provision of Land Registration, as well as the standards recommended by the IAAO.

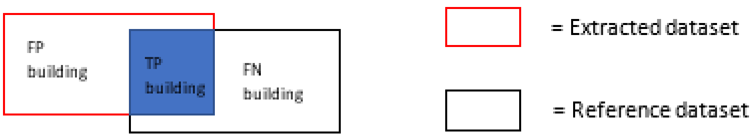
Guideline No. 2 of 2017 from ATRBPN about working map creation using drones
According to the guidelines for UAV usage to create a working map, the tolerance limit for CE90 is defined as "0,5 mm × map scale." For a recommended map scale of 1:1.000, the maximum permissible error is 0,5 meters. The evaluation of the checkpoints revealed that the CE90 of the selected model is 0,46 meters, which is within the acceptable error margin. Thus, it can be concluded that the accuracy of the orthophoto produced conforms to the map standards required for the land sector, particularly for residential and urban areas.

4.3.1.2 Extracted building and boundary validation

The validation process consists of two stages: building validation and boundary validation. Building validation assesses the quality of detection and classification, while building boundary validation evaluates the proximity of the extracted boundary to the reference boundary (delineated boundary).

Building validation
The first step of building validation process is categorize the building footprint into three classes:

a. True Positive building (TP building) shows correctly identified building area (i.e., both extracted and referenced dataset identify buildings).
b. False Positive building (FP building) means that extracted dataset identifies buildings, but reference dataset not.
c. False Negative (FN building) gives that reference dataset identifies buildings, but extracted not.



Validation can be done based on a pixel-based approach if in a raster as in (Brooks et al., 2015) or segment-based (Gavankar and Gosh, 2018). If the overlay is done in vector form as in this thesis, then the validation approach is area-based. In this thesis, building validation is carried out in an area-based and object-based evaluation approach.

Measures of agreement sought are:

a. Completeness (Comp. building).
   Completeness (building) or Comp (building) returns the percent of correctly detected of the buildings.
   It is formulated as:

$$Comp\ (building) = \frac{TP\ building}{TP\ building + FN\ building} \times 100\% \qquad \text{(eq. 32)}$$

In area-based evaluation, the formula can be read as:

$$Comp\ (building) = \frac{Area\ extracted\ buildings\ that\ are\ actually\ building}{Total\ area\ building\ in\ a\ site} \times 100\% \quad \text{(eq. 33)}$$

Where, in object-based evaluation, it says as:

$$Comp\ (building) = \frac{Number\ of\ extracted\ buildings\ that\ are\ actually\ building}{Total\ number\ of\ building\ in\ a\ site} \times 100\% \quad \text{(eq. 34)}$$

b. Correctness (Corr. building).
It shows the percent of true buildings from the extracted dataset
It is formulated as:

$$Corr\ (building) = \frac{TP\ building}{TP\ building + FP\ building} \times 100\% \quad \text{(eq. 35)}$$

In area-based evaluation, the formula can be read as:

$$Corr\ (building) = \frac{Area\ extracted\ buildings\ that\ are\ actually\ building}{Total\ area\ of\ extracted\ building} \times 100\% \quad \text{(eq. 36)}$$

Where, in object-based evaluation, it says as:

$$Corr\ (building) = \frac{Number\ of\ extracted\ buildings\ that\ are\ actually\ building}{Total\ number\ of\ extracted\ building} \times 100\% \quad \text{(eq. 37)}$$

c. Quality (Qual.).
It measures the percentage of the quality of detection. It is a compound performance metric, reflects both completeness and correctness (Weng, Quattrochi, Gamba, 2018).
It is formulated as:

$$Qual\ (building) = \frac{TP\ building}{TP\ building + FP\ building + FN\ building} \times 100\% \quad \text{(eq. 38)}$$

In area-based evaluation, the formula can be read as:

$$Qual\ (building) = \frac{Area\ extracted\ buildings\ that\ are\ actually\ building}{Total\ area\ of\ extracted\ building\ in\ the\ output} \times 100\% \quad \text{(eq. 39)}$$

Where, in object-based evaluation, it says as:

$$Qual\ (building) = \frac{Number\ of\ extracted\ buildings\ that\ are\ actually\ building}{Total\ number\ of\ extracted\ building\ in\ the\ output} \times 100\% \quad \text{(eq. 40)}$$

d. Branch factor (Jin and Davis, 2005; Brooks et al., 2015). This metric measures the rate of inaccurately labeled building pixels or overdetects building (Zeng et al., 2013). Score closer to 0 (zero) indicates a low level of inaccurate labeled building or better branch factor result (Shufelt, 1999).

$$Branch\ factor = \frac{FP\ building}{TP\ building} \quad \text{(eq. 41)}$$

e. Miss factor (Jin and Davis, 2005; Brooks et al., 2015). It denotes the the rate of missed building pixels or under detects buildings (Zeng et al., 2013). Score closer to 1 indicates high level of missed building pixels or worse miss factor result (Shufelt, 1999)

$$Miss\ factor = \frac{FN\ building}{TP\ building} \quad \text{(eq. 42)}$$

Table 34 shows the result of building validation in area-based evaluation

Table 34. Assessment result of OBIA and Mapflow.AI (area-based evaluation)

Assesment	Site 1		Site 2	
	OBIA Analysis	Mapflow.AI	OBIA Analysis	Mapflow.AI
TP building (sqm)	37.928,31	24.812,86	47.720,96	33.772,18
FP building (sqm)	2.737,19	4.077,14	3.828,54	6.705,6
FN building (sqm)	2.053,5	16.535,51	5.554,34	21.330,05
Result				
Branch factor	0,07	0,16	0,08	0,19
Miss factor	0,05	0,66	0,11	0,63
Completeness (%)	94,86	60	89,57	61,29
Correctness (%)	93,26	85,88	92,57	83,43
Quality (%)	88,78	54,62	83,56	54,64

Below is the result of building validation in object-based evaluation

Table 35. Assessment result of OBIA and Mapflow.AI (object-based evaluation)

Assesment	Site 1		Site 2	
	OBIA Analysis	Mapflow.AI	OBIA Analysis	Mapflow.AI
TP building	268	270	347	269
FP building	32	171	40	84
FN building	22	274	65	294
Result				
Branch factor	0,11	0,63	0,11	0,31
Miss factor	0,08	1,01	0,18	1,09
Completeness (%)	92,41	49,63	84,22	47,77
Correctness (%)	89,33	61,22	89,66	76,20
Quality (%)	83,22	37,76	76,76	41,57

The evaluation results in Table 35 demonstrate that the OBIA analysis performed better across both Site 1 and Site 2. In both sites with area-based and object-based validation, it reaches at least 76,7%

quality of building extraction. On the other hand, extracted building quality from Mapflow.AI was only as high as 54,6%. The lack of completeness is giving a major effect of quality as well as a high miss factor on Mapflow.AI results even though the correctness validation still has some decent scores. Although overall the results from OBIA are of higher quality, when considering area-based or object-based metrics, the number and size of buildings classified as true positives do not differ significantly. Because both methods use training sets for classification, it suggests a similar tendency in how both techniques process image data, especially in analyzing roof colors, building shapes, and distances between buildings.

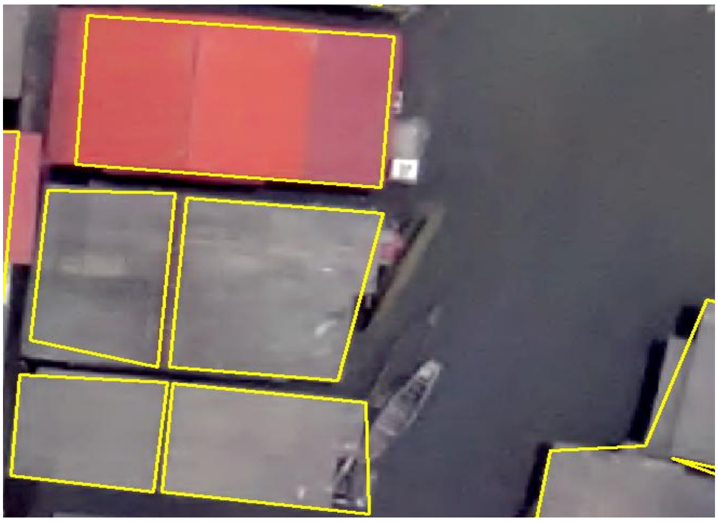


Figure 55. True positive building

Simple-shaped building roofs like rectangles are easier to extract and also result in cleaner boundaries, while more complex roof shapes usually result in a different shape than the correct one. The color of the roof also significantly influences the extraction process, as a color contrast with seawater facilitates better extraction. The denser the buildings, the more difficult it is to extract because the boundaries between them become blurred.

Pairwise analysis of Matched, Failed, Under-bordered, and Over-bordered.

Because it is a semi-automatic segmentation process (still involving human knowledge), categorization is also performed visually to evaluate and better understand the differences between the outputs of both methods. This categorization was applied to the OBIA result as as it demonstrated better performance. We can classify the result into four different types.

a) Matched (M).
A matched condition happens if an extracted building successfully shows the same parameter as the one provided by the reference building.
b) Failed (F).
The extracted boundaries fail to separate (some buildings are entirely undetected in the reference dataset), or less than 50% of the building boundary on the reference dataset is identified in the extracted dataset
c) Underbordered (U).
Extracted buildings do not manage to separate buildings as in the dataset reference. In other words, there are building boundaries that have not been extracted successfully, so there are buildings that refer to the data set as three buildings, in extraction they are only one building.
d) Overbordered (O).
Extracted boundaries create too much separation. In other words, the extraction dataset consists of two or more buildings, whereas in the reference dataset there is only one building.

The comparison of percentage results allows us to identify the quality of the boundaries generated in the study site (whether the detection is over, under, or exact), while also helping to identify problems that occur in the boundary separation process related to differences in color, distances between houses, etc. Identification of features on buildings that can complicate the identification process. Ultimately, this provides insights into recommendations for the types of buildings suitable for this semi-automatic segmentation.

Table 36. The number of buildings in each class.

Assesment	Site 1		Site 2	
	Number	%	Number	%
Matched	43	32,09	99	45
Failed	37	27,61	85	38,64
Underbordered	54	40,30	17	7,73
Overbordered	0	0	19	8,64
Total	**134**	**100**	**220**	**100**

From the percentage of Match category, it can be observed from Table 36 that the extraction process provides slightly better results on Site 2. The visual quality of the image on Site 2 (with more upright building shapes and larger scale) may have facilitated the extraction process.

Upon closer visual examination, it can be observed that each category tends to following some patterns (i.e., match specific settlement and building characteristics).

a. For Matched category.
   - In Site 1, buildings that are clearly separated, either by bodies of water or roads, from surrounding buildings.
   - In Site 2, buildings that are clearly separated, either by bodies of water or roads, from surrounding buildings. Additionally, in Site 2, it was found that matched buildings are those located in water (5 matches out of 8 buildings).

b. For Failed category.
   It represents detection failures. There is no specific pattern found, similar to the characteristics of categories U and O.

c. For Underbordered category.
   For both Site 1 and Site 2, the buildings categorized as "Under" are predominantly those with unclear or too close proximity to neighboring buildings. In Site 2, they are generally located in irregular settlement clusters.

d. For Overbordered category.
   For both Site 1 and Site 2, the buildings categorized as "over" also happen to have blurred borders between each other.

Therefore, although in general, the semi-automatic segmentation method in this research produces unsatisfactory results for building boundaries, it can still be stated that there are types of buildings and settlement clusters that have potential for application. These include clusters that are regular and have clear, separated boundaries between buildings (either by roads or bodies of water). In this regard, water-locked buildings are a type of structure suitable for boundary extraction through semi-automatic segmentation methods. Since the assessment of boundary accuracy is only feasible when the boundaries are matched between extraction and reference, the assessment is limited to the Matched category only.

Boundary Validation

Only buildings classified as Matched from OBIA analysis underwent boundary validation. This is because buildings categorized as Failed, Under, or Over are already known to have inaccurate boundaries and therefore do not require validation. In the validation process, a 100 cm buffer was used as a tolerance to assess the agreement between extracted and reference boundaries (Figure 56)

To further clarify it can be seen in the following visual illustrations:

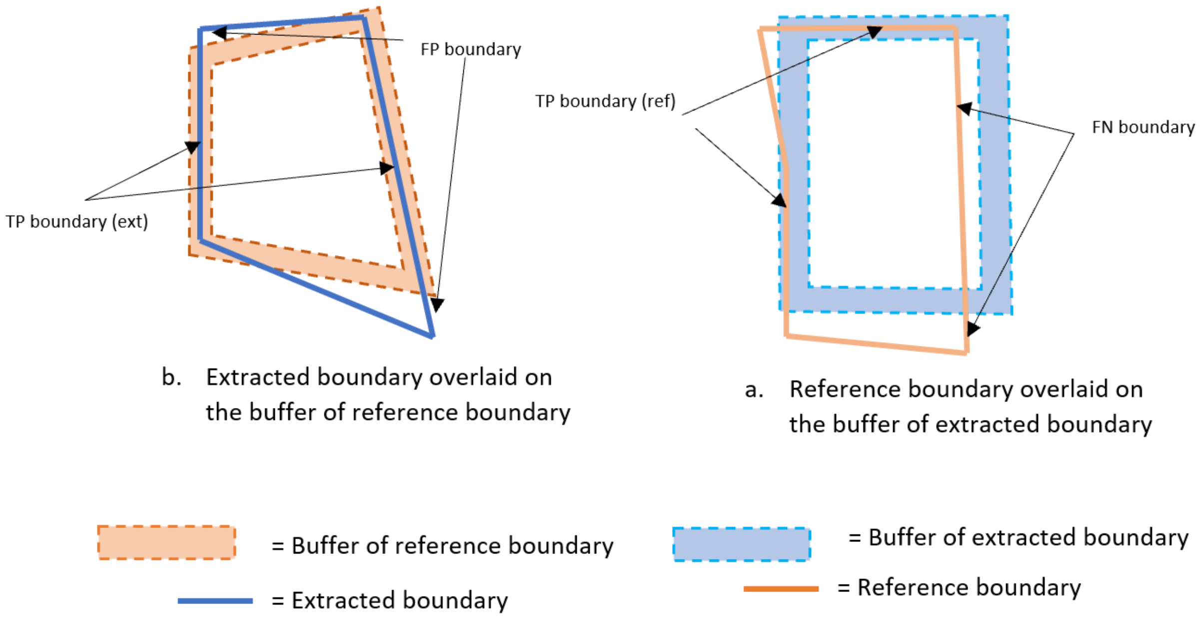


Figure 56. Illustration of reference and extracted boundary

Measures used are also Completeness, Correctness, dan Quality.

a. Completeness (boundary).
   Comp. (boundary) returns the percentage of the reference boundary that overlaps with the buffer of extracted boundary.

   It is formulated as:

$$Comp\ (boundary) = \frac{length\ of\ the\ matched\ reference}{total\ length\ of\ the\ reference\ boundary}\ x\ 100\%$$

$$\approx \frac{TP_{boundary(ref.)}}{TP_{boundary\ (ref.)} + FN_{boundary}}\ x\ 100\% \qquad \text{(eq. 43)}$$

b. Correctness (boundary).
   It shows the percentage of the extracted boundaries that overlap with the buffer of the reference boundaries.

$$Corr\ (boundary) = \frac{length\ of\ the\ matched\ extraction}{total\ length\ of\ the\ extracted\ boundary}\ x\ 100\%$$

$$\approx \frac{TP_{boundary(ext)}}{TP_{boundary(ext)}+FP_{boundary}} x\ 100\% \quad \text{(eq. 44)}$$

c. Quality (boundary).
   It measures the percentage of overall quality in boundary extraction, which is a combination of completeness and correctness.

$$Qual\ (boundary) = \frac{total\ length\ of\ the\ boundary\ in\ the\ buffer}{total\ length\ of\ the\ boundary\ in\ the\ buffer + total\ length\ of\ boundary\ not\ in\ the\ buffer} x\ 100\%$$

$$Qual\ (boundary) = \frac{TP_{boundary}}{TP_{boundary} + (FP_{boundary}+FN_{boundary})} x\ 100\% \quad \text{(eq. 45)}$$

The validation process converted the buildings' polygon into lines and then buffered them. We calculated True Positive (TP), False Positive (FP), and False Negative (FN) counts, following previous procedures. Since the focus is on boundaries, they are referred to as TP boundary, FP boundary, and FN boundary.

a. TP boundary represents the length of boundaries from the extracted data that fall within the buffer of reference boundaries. It includes two components: TP boundary (ext.) indicates matched extracted boundaries to the buffer of reference boundaries; and TP boundary (ref.) denotes matched reference boundaries to the buffer of extracted boundaries.
b. FP boundary indicates the length of extracted boundaries that do not fall within the buffer of reference boundaries.
c. FN boundary refers to the length of reference boundaries that are not detected and do not fall within the buffer of extracted boundaries.

Table 37. Result of boundary validation in object-based evaluation

Assessment	Site 1		Site 2	
	OBIA Analysis	Mapflow.AI	OBIA Analysis	Mapflow.AI
TP ext (m)	3.069,92	2.807,44	4.214,31	1.390,76
TP ref (m)	2.114,81	2.897,23	4.232,02	1.429,85
FP (m)	325,92	429,65	685,26	477,09
FN (m)	49,11	771,51	510,9	675,75
Result				
Completeness (%)	97,73	79,97	89,22	67,90
Correctness (%)	90,40	86,72	86,01	74,45
Quality (%)	93,25	82,60	87,59	70,98

Table 37 shows that OBIA exhibited better performance than Mapflow.AI in building footprint extraction at both sites.

4.3.2 Operability evaluation

4.3.2.1 Duration

Following the Regulation of the State Minister of Agrarian Affairs/Head of National Land Agency on Standard for Land Service and Arrangement (BPN, 2010), Ramadhani et al. (2018) mentioned that the time of cadastral surveys varies depending on their objective. The border reconstruction process takes a maximum of 12 days for areas smaller than 40 ha, and 30 days for areas larger than 40 ha. Ramadhani's study explores that generally the approach using a conventional terrestrial survey took 1 day, 7 hours, and 10 minutes of working time for the measurement of 1 parcel. In the terrestrial survey, the duration is extended as the individual claiming the property is informed to reach an agreement with the neighboring parties regarding the boundary of the parcel. Additionally, they are required to prepare the boundaries to be demarcated by monuments or signs in order to resolve any disputes related to the delimitation. The delay resulting from disagreements over boundaries or the absence/uncertainty of boundary markers will result in a delay of the entire procedure. It is generally known that, depending on the conditions, a GPS survey team could measure about 10 parcels per day in rural areas and up to 15-20 parcels per day in more accessible, flat urban areas. However, the GPS surveying can be slower in areas with poor satellite reception or in areas with many obstructions, reducing efficiency to around 5-10 parcels per day.

The results of our field experiment indicate that, under normal conditions, measuring a single boundary point of an aquatic land parcel typically requires approximately five minutes. Given that a standard parcel generally has four boundary corners, the total time required per parcel amounts to 20 minutes. Considering an eight-hour workday, this time frame equates to the measurement of approximately 24 parcels per day within the study area. In contrast, as demonstrated in Table 38, the UAV-based imaging approach required a total of 6.981 minutes, or approximately 13,58 days (14 days), to generate data for 3.956 parcels, assuming an eight-hour workday.

The evaluation showed that the UAV survey was more time-efficient than the conventional survey. Unlike conventional surveys that require significant user intervention, the UAV approach largely relies on computational processing that can minimize the duration and user interaction.

Table 38. Calculation of duration

No.	Stages of work	Volume	Unit of measurement	Working time per one volume	Total duration		
				(hours)	(hours)	(minutes)	Days (8 WD)
1	Preparation (i.e., charging, permit, vehicles)	1	Project	8	8	480	
	Sub total				***8***	***480***	***1***
2	GNSS survey						
	- Reconnaisance	1	Project	6	6	360	
	- Premarks (GCPs) installation	8	Pillars	1	8	480	
	- GCPs measurement						
	Setting up the unit	8	Location	0,33	2,67	160	
	Data acqusition	8	Points	1	8	480	

Table 38 (continued)

	Mobilisation (movement from a point to another point)	8	Movement	0,5	4	240	
	- Processing						
	Setting project	1	Project	0,25	0,25	15	
	Import data	1	Project	0,25	0,25	15	
	Baseline processing/editing	1	Project	3	3	180	
	Export results	1	Project	0,25	0,25	15	
	Sub total				***32,42***	***1.945***	***4,05***
3	UAV survey and processing						
	- Reconnaisance	1	Project	3	3	180	
	- UAV data acquisition						
	Setting up the unit	1	Location	1,5	1,5	90	
	Flying time	1	Project	6	6	360	
	- UAV image processing work						
	Loading, inspecting, and aligning photos	1	Project	2	2	120	
	Building dense point cloud	1	Project	2	2	120	
	Building mesh (3D polygonal model)	1	Project	2	2	120	
	Corrections using GCPs	1	Project	1	1	60	
	Camera optimization	1	Project	0,25	0,25	15	
	Building DEM	1	Project	1	1	60	
	Building orthomosaics	1	Project	2	2	120	
	Export results	1	Project	1	1	60	
	Sub total				***18,75***	***7.506***	***2,34***
4	GIS work						
	Digitization and editing	3.956	Parcels (buildings)	0,01	49,45	2.967	
	Sub total				49,45	2.967	***6,18***
	TOTAL				**108,62**	**6.517**	**13,58**

4.3.2.2 Affordability (cost)

Terrestrial survey cost

The fees and duration of the terrestrial survey were stipulated in the Government Regulation on Fees of Non-Tax Revenue for National Land Agency No. 128 of 2015. The surveying tariff can be calculated following the formula as below:

$$Tu = (L/500*HSBKu) + 100.000 \quad \text{(eq. 46)}$$

Where:

Tu = measurement tariff
L = area (in m^2)

HSBKu = fixed fee based for rural or urban area in a province (in IDR), stipulated in in Regulation of the State Minister of Finance on Index Rate Calculation of Non-Tax Revenue No. 132/PMK.02/2010, for Riau Island Province, the HSBKu is stipulated as much as Rp100.000

Based on GIS calculations, the average area of aquatic land parcels in the UAV study area is 146.5 m2. Then using the formula approach, you can know the average tariff as follows:

Tu = (146,5/500*100.000) + 100.000
Tu = 129.300 (in IDR)

This is a cost per parcel. The number of parcels in the AOI is 3956, then the total cost of the measurement required is Rp511.510.800

UAV survey cost

To do an analysis of the UAV survey cost, as a reference, we took a few regulatory sources regarding the costs of activities and personnel in survey and mapping work. From the calculations, can be seen in the Table 39, the total cost required to carry out the UAV mapping and GIS work to generate boundary for an area of about 400 hectares (+- 3956 parcels) is Rp36.740.000.

Table 39. UAV survey cost

No	Operational/Recurrent costs	Price per unit (IDR)	Vol	Measurement unit	Occupation/ paid day		Total price	Source of price information
1	Staff salaries + staf allowances (per diem, housing)							Regulation from Geospatial Information Agency No 11/2016 on Prices Standards Processing Activities Generalisation of Geospatial Information on 2017
	UAV survey							
	- Analyst	1.130.000	1	Person	3	day	3.390.000	
	- Pilot	910.000	1	Person	3	day	2.730.000	
	- Assisstant	580.000	1	Person	3	day	1.740.000	
	GCPs survey and processing							
	- Surveyor	1.130.000	1	Person	4	day	4.520.000	
	- Assistant	580.000	2	Person	4	day	4.640.000	
	UAV and GIS processing work							
	- Operator	580.000	1	Person	9	day	5.220.000	
3	Equipment (i.e., software, hardware, survey equipment)	Rental					Rental	
	- UAV fixed-wing rent + including software (agisoft photoscan)	3.000.000	1	Unit	3	day	9.000.000	UAV rental company (Seribu Bintang Aero Modeling)
	- GNSS Geodetic Trimble double frequency, including software (TBC)	600.000	1	Package	3	day	1.800.000	Indonesian Corporate Association of Geospatial Information Survey and Mapping and the author's record during field data collection

Table 39 (continued)

	- High specification laptop rent	200.000	2	Package	3	day	1.200.000	
4	Occupation expenses (i.e., building rents, utilities)			N.A.				
5	Contract service			N.A.				
6	Repairs and maintenance			N.A.				
7	Vehicles and vehicle operation expenses (for UAV and GNSS project) rental	350.000	2	Project	3	day	2.100.000	According to the common expenses of car rental plus gasoline in Tanjungpinang
8	Materials (i.e., Premark materials) and consumables	200.000	2	Project	-	-	400.000	The author's record during field data collection
	TOTAL			All parcels			36.740.000	IDR

Note:

- This is the cost breakdown for the UAV orthoimage acquisition of approximately 400 hectares.
- The salary for staffs is made for daily basis. Although the staffs work in a day less than 8 hours, under this payment model, they still get paid for a day work.
- The equipment rental period spans the entire project process. However, this may not coincide with the actual deployment duration for data acquisition.
- One working day is 8 hours.
- The equipment cost was derived from a rental procedure. If all equipment are bought under new procurement scheme, the cost will be much higher.
- Point 4, 5, and 6 are assumed to be non-existent factors in this UAV survey, and hence they are marked as non-applicable (N.A.).

5 LAND VALUE ESTIMATION

5.1 INTRODUCTION

This chapter addresses Objective 3. The approach is first identified and described. Following this, variables, resulting models, their performance, and the final GIS-made land value map are presented. The discussion part then covers the evaluation results concerning the UAV-based survey system's role in supporting land valuation, with reference to fit-for-purpose criteria.

Land valuation, or land appraisal, is a broad term that encompasses several methods and approaches used to determine the monetary worth of a piece of land. Land valuation can be categorized into two main types: area assessment, which involves evaluating the economic, socio-ecological, and environmental worth of a given region, and land parcel valuation, which focuses on assessing the value of land parcels (Directorate of Land Valuation, 2014). Contrary to area assessment, which does not rely on market prices, land parcel valuation typically incorporates market prices into its evaluation. In the context of residential areas, the term "land valuation" is frequently employed synonymously with "real estate valuation" or "real property valuation." This study refers to property as a structure or structures along with the land, encompassing the interests, advantages, and entitlements associated with land ownership, as well as any fixtures or objects that are permanently affixed to the land or legally classified as immovable (IAAO, 2013).

A key objective of fit-for-purpose land valuation is to generate land value adhering to cadastre principles suitable for a given purpose. This means appraisal approaches, methods, and techniques used in valuation and model creation are adaptable to requirements (i.e., why land's value is determined), sensitive to assessment area attributes, and do not prioritize the sophistication of the approach.

One fundamental idea in fit-for-purpose land valuation is using spatial data from aerial photography or satellite imagery. This involves identifying and extracting characteristics impacting valuation, and incorporating spatial variables into the modeling process. Due to the fact that the outcomes are primarily utilized for cadastre objectives—specifically fiscal cadastre (taxation) and juridical cadastre (land registration)—land parcel valuation is also occasionally denoted as cadastral valuation, and the outcomes of the evaluation are known as cadastral value.

Land parcel valuation encompasses appraising land and assessing additional components situated above or below it. If the purpose of the appraisal is only to obtain the value of land, then the additional component value (e.g., buildings) will be calculated separately with regard to their depreciation and excluded in the further calculation process.

Land valuation in Indonesia

Land is the most important factor in all human activities, especially the fulfillment of economic needs. This makes land the main element of all activities carried out by humans, both social, economic, commercial, and others. The land area is relatively fixed, making land a scarce resource and of high economic value. The shortage of land is due to the need for land for various activities such as industry, trade, services, settlements, agriculture, fisheries, plantations, transportation, forestry, animal husbandry, and other activities, even though the available resources are limited. The diversity of land uses for various needs makes land a very attractive product for investment purposes and can generate significant profits.

The increasing value of land will provide benefits to people who want to invest in the land. Socially desirable goods have relatively higher prices than socially undesirable goods. People's desire to own land is generally more concentrated in urban areas, while land funds available in these areas are usually limited, leading to the sharpest increase in land values in urban areas. This is in accordance with Dunkerley's statement (1983 in Hermit, 2009), which states that the largest increases in land prices occur in urban areas, especially in developing countries, due to the strong expansion of their communities.

The high land value in urban areas is not necessarily comparable to the value of the surrounding land. According to Von Thunen (1826 in Hermit, 2009), differences in distance from the city center or business center (CBD) cause differences in land values between locations. In this case, the highest land value is in the downtown area, followed by the transition area, and finally the suburban area. The phenomenon of differences in land values is caused by factors that affect land values. There are many factors that affect land and property values. According to the technical guidelines of the Directorate of Land Valuation (2014), there are several factors that can affect land value, among others: (a) factors related to land ownership status (HM, HGB, or uncertified); (b) soil physical factors (land area, land shape, land location and elevation); (c) environmental factors (quality/type of nearby roads, accessibility, drainage, utilities and public facilities).

In Indonesia, land valuation's final purpose is to acquire the value for land only (without buildings ot other components). The results function for several things, as follows:

1. Land registration.
   Land value is used in the derivative land registration to calculate the non-tax state revenue rate (PNBP) for land service activities:
   a. Extension and renewal of rights.
   b. Transfer-purposes registration (sale and purchase, gift, exchange).
2. For tax purposes: to be a reference for determining NJOP (Tax Object Sales Value). NJOP is used by local governments as a basis for calculating BPHTB (Land and Building Rights Acquisition Fee) and PBB (Land and Building Tax).
3. As a reference in calculating compensation in land acquisition activities in accordance with Land Acquisition for Development in the Public Interest (Article 36 of Law No. 2 of 2012).

Until today, the assessments to estimate land values in Indonesia by the competent authorities (i.e., ATR/BPN and the Regional Government via the Regional Revenue Service) have been based on empirical assessment, and the resulting land values have been generated through calculations and adjustments based on ratings and scoring. This thesis drives further by trying to provide values by developing a simpler method of mass land evaluation based on land parcel (parcel-based mass valuation).

5.1.1 Approach and model development

Generally, there are three common approaches or assessment methods: the market data, cost, and income approaches. Contingent upon the specific data, conditions, type of properties, and objectives of valuation, the mixture of all those approaches can be used or just one or two of them combined, to estimate land value. This study utilized a combination of the market data approach and the cost approach.

The market data approach is a way of calculating the market value of a property based on the selling price or offering price of other similar properties. This approach has three principles: supply and demand, balance, and substitution. Supply and demand means that the determination of property value is based on market conditions. This process demands mutual agreement between the seller and buyer, both of whom possess the requisite knowledge. Balance is is an extension of the principle of supply and demand, positing that demand and supply will perpetually equilibrate and converge towards a state of equilibrium between the two. Substitution is the principle that a property's value is consistently established by the monetary investment required to acquire a replacement property that is equal in terms of use, anticipated profits, benefits, and functionality. The properties being valued must be comparable, so the formula is „Property Indicative Value = Property selling price + adjustments".

Meanwhile, the cost approach is a method of estimating or interpreting the costs spent on acquiring, producing, or building property at the time/time present in new conditions, reduced by depletion, reduction, or depression of property, and then added to the estimated value of land (Directorate of Land Valuation BPN, 2014). The approach can be implemented through five steps (1) Assessment of land in empty condition using market data approaches to get Land Value (LV), (2) Interpretation/estimation of replacement value or replacement cost new (RCN) of the current improvement or development, (3) Calculation of depreciation/depression that occurred during the lifetime of the building, (4) Determination of the Indicative Value of the building by reducing the RCN with the depreciation or depression value of the building, which can be calculated physically (physical deterioration), functionally (functional obsolescence), or economically (economic obsolescence), (5) The property value is obtained by adding the Indicative Value to the Land Value.

5.1.2 Techniques

There are two systems or methods of property valuation: mass and individual valuation (Table 40). Mass valuation is defined as a systematic assessment of a group of property units performed at a given time using standard procedures and possibility of statistical analysis (Kathman, 1993). Individual evaluation refers to the process of evaluating each singular unit of property. This thesis will deploy a mass valuation model.

Characteristics of mass and individual valuation (Eckert, Gloudemans, and Almy (1990):

Table 40. Mass and individual valuation main characteristics

Mass valuation	Individual valuation
Use standard procedures for same of almost the same property	Use “judgement calls” that are individual to each property
Quality control by using statistical methods by calculating sales price deviations	Quality control by comparing sales prices on other properties
Refer to legal standards and standards of the appraiser profession	Refer to standards of the appraiser profession

Over the past decades, mass property valuation has progressed from simple empirical methods and manual judgments to more sophisticated automated valuation models (AVMs). With advances in technology, modeling methods such as the Adaptive Estimation Procedure (AEP) and Artificial Neural Networks (ANN) have emerged.

Development of model

In estimating the value of aquatic land parcels in the coastline settlements, we use hedonic land valuation model. Hedonic land valuation is a method used to estimate land values by analyzing how various attributes of a property contribute to its price (Monson, 2009). This approach is based on the hedonic pricing model, which assumes that a property’s value is determined by a combination of its characteristics.

This insight suggests that the presence of certain factors around a group of land parcels will likely impact the value of land within and surrounding that group. When these factors are consistently present over space and time, they are expected to form a structured land value zone. Therefore, it is valuable to conduct a land valuation study that assesses each plot based on the total score of factors believed to influence land value. Additionally, the development of land value tends to align with the characteristics of the region and specific land parcels, reflecting regional or urban development patterns. From this perspective, researchers estimate that changes in land values will spatially correspond to changes in the characteristics of land plots. This leads to the understanding that plots of land with significantly different factors and characteristics will exhibit significant differences in value. If the internal and external attributes of a plot differ, the land's value will also vary depending on its spatial and temporal context. The extent of these differences in land values can be observed through individual assessment of the varying characteristics of the parcels.

When estimating the value of thousands or tens of thousands of land parcels, individual assessment are impractical. A mass land valuation system is necessary for efficiency. This system allows for estimating the value of many parcels based on representative land samples. Researchers have developed various approaches for mass land valuation, including applications using Artificial Neural Networks (ANN) in Matlab, enhanced with a Graphical User Interface (GUI). More recently, the Random Forest algorithm in Python has been utilized for this purpose. These applications use representative samples to build estimator models, which are then applied to estimate the values of all parcels. However, a key limitation is the complexity of the methods (Bilgilioğlu and Yılmaz, 2021), and the gap between the estimates and the samples. The application has weaknesses in its construction because it must be designed by competent human resources in the field of information technology and the results of land value estimates are different from sample values. These methods are still considered too complicated because they involve many algorithms that are not easy for many people to understand.

To address this issue, we developed an efficient method that attempts to provide the estimates closely aligned with the sample values. The proposed method uses the estimator equation to calculate the value of unassessed parcels by comparing the sample scores with the total scores of the parcels. To reduce bias, the total scores are grouped into categories with minimal differences, creating land value zones. In each zone, at least one land transaction or demand value sample is selected and adjusted to reflect transaction prices. Based on these samples, the values of other parcels in the zone are estimated. This approach is applied across all zones. The score-comparison technique can be accurately performed using computer-assisted valuation, while still providing reliable market value estimates. The score-comparison technique is based on the insight from Sudirman et al. (2013), who asserted that the value of land remains stable when it aligns with the specific characteristics of the territory and the land itself, in accordance with the development of the surrounding area. The researchers suggest that fluctuations in land value are likely to reflect variations in the distinct features present in different land areas. Consequently, if a parcel of land shares similar variables and attributes with its surrounding area, its value is expected to exhibit minimal variation.

If each affecting factor/characteristic of a piece of land is given a different number of points (score) depending on how it affects the value of the land, then the total score of parcel can be the sum of those scores, and thus become the indicator of the value of the land parcel concerned. For example: if a parcel has a total characteristic score, for example 45, and have been traded so that it has a value, for example Rp 650.000/m2 (Parcel A), and another parcel also has a total score of 56, but not yet the subject of the transaction (Parcel B), then the actual value of B can be estimated based on the land value of A. The land value B based on the value of A can be calculated using the following formula.

$$Value\ of\ Parcel\ B = \frac{Total\ score\ of\ Parcel\ B}{Total\ score\ of\ Parcel\ A}\ x\ Value\ of\ Parcel\ A \qquad \text{(eq. 47)}$$

The formula above shows that the land value of B is = (56/45) x Rp650.000 = Rp808.886, rounded up to Rp800.890.

5.2 VALUING AQUATIC LAND IN THE COASTLINE SETTLEMENTS

5.2.1 Influential factors of land value

While defining a correct approach is crucial to guaranteeing the performance of a valuation model, selecting the proper factors through meticulous exploration is also important to bringing the estimated model as close as possible to reality. Usually, the selection process takes two necessary actions: literature reviews and field observation. The review provides a foundational understanding of factor selection and the necessary considerations. The observation would identify the factual characteristics of the valuation area and give a sensible reason for why we select or put aside a factor from the valuation process. The factors themselves can belong to the economic, social, law-government-politics, and physical-environment-location groups (Eckert et al., (1990).

Economic factors

Economic factors generally relate to a country's economic situation and activities at the local, regional, and national levels. These factors can also be observed from a demand-supply perspective. Income level, purchasing power, interest rate, and transaction costs are some examples of the demand, whereas numbers of land parcels, land development costs, taxes, and ownership costs are examples of the supply.

Social factors

According to Chou and Stoykova (2013), social factors are those linked to ethnic and societal characteristics that affect the supply and the demand. Type of society (i.e., communal or not), existence of a social gap and social security system, interaction among ethnic groups, views towards land, population change, gender/age composition, and education belong to this group.

Law- government-politics factors

These factors are often called regulation factors, or government factors, because they relate to property policy and regulations issued by the government. Some examples of these factors are the regulation of land management and spatial planning, land use restrictions, and property tax policy and rate.

Physical-environment-location factors

This group reflects the physical and environmental conditions concerning the geographical position of the property. Britton et al. (1989) and Cohen and Coughlin (2007) argue that the geographical position of the property is very influential, expressing the traditional mantra used to describe the three main factors affecting the value of real estate as "location, location, and location". The physical attributes include plot and building size, topography, plot and building shape, frontage, building age, and other internalities. Environmental attributes are related to environmental quality and amenities, as well as the availability of utilities, infrastructure, and services in the neighborhood. Location factors are attributed to accessibility and spatial connection.

Following such classification, we then explored 10 previous studies to find out what the factors were and what the rationales were when choosing the factors. Our study is about a residential valuation, so the studies we took are the ones that applied to the residential area, not the industrial, agricultural, or tourism area. None of them researched coastlines or aquatic land valuation, which is the specificity of this research, but at least an understanding of the principles and considerations would be constructive for this research. Table 41 shows our identification result.

Table 41. Previous research of land valuation

Economic (1)	Social (2)	Law, government, and politics (3)	Physical, Environment, Location		
			Physical (4)	Environment (5)	Location (6)
Weiss, Donelly, and Kaiser (1966). Land value and land development influence factor: An analytical Approach for Examining Policy Alternatives in North Carolina's Piedmont Crescent, USA					
	▪ Dwelling density	▪ Zoning protection ▪ Suitability of buildings ▪ Proximity to non-white area		▪ Residential amenity ▪ Availability to work, sewage, and clean water	▪ Distance to major street, nearest elementary school, recreation area, and shopping area ▪ Total travel distance ▪ Accessibility to work area ▪ Proximity to blighted area
Mc Millen and McDonald (2002) Land value in a newly zoned city in Chicago, USA					
▪ District average home value	▪ District percentage of multifamily		▪ Buildings age ▪ District Percentage rental		▪ Distance to town center, Lake Michigan, El Station, commuter train station, and river ▪ Proximity to railway and main road
Yomralioglu and Nisanci (2004). Nominal asset land valuation technique by GIS					
		▪ Permitted number of floors 3 ▪ Permitted construction area	▪ Shape ▪ Street frontage ▪ Soil condition ▪ Topography	▪ Supplied basic services ▪ Landscape view ▪ Currently usable area ▪ Available utilities	▪ Access to street, highway, waterway, and railway ▪ Parcel location within block ▪ Distance from nuisances and from noise ▪ Distance to city center, educational centers, health services, shopping center, recreational areas, religious place, play garden, car parking area, fire station, and police station
Leksono et al. (2008). Automatic land and parcel valuation to support the land and building tax information system by developing the open source software					
▪ Mean income ▪ Credit ▪ Job chance ▪ Economic activities	▪ Security ▪ Social gap ▪ Culture ▪ Density	▪ Legal status	▪ Topography (contour) ▪ Land use ▪ Soil condition	▪ Availability of electricity, drainage, gas supply, phone line ▪ View amenity	▪ Hook parcel or not ▪ Distance to air pollution, public transportations, main roads, hospitals, and schools

Table 41 (continued)

Demetriou (2018). Automating the land valuation process carried out in land consolidation schemes					
▪ Land productivity ▪ Purchasing-power parity (PPP)		▪ Existence of irrigation rights	▪ Size ▪ Shape ▪ Slope ▪ Elevation ▪ Aspect ▪ Existence of a stream ▪ Soil type	▪ Existence of sea view	▪ Access through a registered road and a registered pathway ▪ Distance from residential zones and the main road
Hafiz (1994) in Ismail and Buyong (1998). Residential Property Valuation using GIS					
▪ Date of transaction	▪ "Fung sui" (a custom belief)		▪ Floor finishes ▪ Deterioration ▪ Building extension and renovation	▪ Landscape	▪ Location ▪ Position of lot
Silalahi (2010). The analysis of influencing factors of urban land price using GIS (Case Study of WP Gedebage, Bandung City)					
	▪ Villages density	▪ Conformity with spatial planning ▪ Legal status	,	▪ Availability of drainage	▪ Distance to arterial road, central business districts, and industrial center
Goffette-Nagot< Isabelle, and Isabelle (2009). A spatial analysis of residential land prices in Belgium: accessibility, linguistic border and environmental amenities					
▪ Accessibility to jobs ▪ Income of commune	▪ Population density		▪ Slope	▪ Percentage of forest and agriculture area ▪ Presence of coast and water (lake or river)	
Yalpir et al. (2014). Creating a valuation map in GIS through Artificial Neural Network methodology: a case study					
▪ Sale price			▪ Number of rooms and stories ▪ Buildings' age ▪ Frontier		▪ Distance to transportation network, green areas, trade centers, and to university

Table 41 (continued)

Ping (2005) Residential land value modelling					
				▪ Neighborhood quality ▪ View of water ▪ Influence of railway and industrial pollution	▪ Travel time to city center, and to school ▪ Access to sub-center, main road, and public transportation ▪ Distance to hospital, post office, to market (shopping)

From our investigation of those studies, we are able to summarize some important points. Firstly, as far as we are aware, there is no binding and one-for-all rule of what factors and how many factors should be used, and from which group. As an example, the research from Silalahi (2010) only used seven factors, without the factors from the economic and physical group. Another example from Silalahi (2010), Leksono et al. (2008), applied 22 factors from all groups, which also varied in number for each group. The physical, environment, and location group were used in all studies, while the factors from other groups were facultatively used.

The selection apparently depends on necessity and area characteristics. If there are buildings in the area of valuation, the buildings' attributes indeed affect the property price. Hence, these attributes need to be considered as affecting factors of property value. Hafiz (1994) used building deterioration and renovation. Yalpir et al. (2014) considered the number of rooms, number of stories, building age, and frontiers (the cardinal direction of the building's front). Besides, in the region where various land tenure forms take place following the continuum of land tenure, tenure status is commonly accepted as one of the affecting factors, as shown by Leksono et al. (2008) and Silalahi, 2010). If there were some factors that gave the same and uniform feedback to the property value, those factors would normally be eliminated from the analysis. Those factors are not relevant for modeling. This condition is also a reason why, in those studies, the involved affecting factors always vary from one another.

Secondly, from the cadastral point of view, among the factors used by those studies, there are cadastral factors and non-cadastral factors. The cadastral factors consist of juridical and physical cadastral datasets. The juridical data in those studies are the date of transaction (Hafiz, 1994), legal status of the property (Silalahi, 2010; Leksono et al., (2008), and conformity to spatial planning (Silalahi, 2010; Weiss, Donelly, and Kaiser (1966). The physical data are property shape and property size (used in Yomralioglu and Nisanci, 2004; Demetriou, 2018), land use, and topography (used in Leksono et al. ,2008). The remaining factors are considered non-cadastral factors.

Thirdly, the incorporation of spatial-related factors reflecting the spatial adjacency and connectivity between properties and features of interest (FOI) or points of interest (POI) is necessary. Those FOIs are the spots, services, or facilities considered important in the region, for example, business centers, transportation services, markets, health centers, religious places, and education centers. Every place would have various important facilities or services, depending on the region's characteristics. If an area is known as a student city, the important facilities or services might be university buildings, schools, a library, or other educational supports. If the area is a coastal city, water transportation facilities and other services and amenities related to the coastal and sea environment would be the important ones. If the coastal areas are prone to disaster, hazards and disaster should be the factors and vice versa.

As shown in Table 41, a commonly used spatial connectivity model is accessibility. Accessibility is characterized by travel time, distance, proximity, and the availability of access. Travel time shows the duration of the journey. Travel time measurement would be operative if the road infrastructure, services' coverage, and punctuality were guaranteed. Distance is a linear measure in metric units. Proximity is a nearness to a certain threshold; for example, if the threshold is 100m, then the straight distance from the center to the threshold could be considered near. Access availability can be seen as the availability of access to transportation facilities and infrastructure in the neighborhood.

Fourthly, it is noticed that the most frequently used factors related to amenities are the ones related to the presence and provision of facilities, services, and infrastructure. However, the usage of leisure attributes (e.g., presence of water, landscape view, water view) was also shown by Weiss, Donelly, and Kaiser (1966), Hafiz (1994) in Ismail and Buyong (1998), Leksono et al. (2008), Demetriou (2018), Goffette-Nagot et al. (2009), and Ping (2005). We also observed that while most factors are relatively general and, to some extent, could be applied to another similar areas, a few are fully contextual and time-specific (i.e., only applicable to the particular time and area). An example of this situation can be seen in Weiss, Donelly, and Kaiser (1966), who selected proximity to the non-white area (the term 'white' refers to skin color) as one of the affecting factors. The social background in America at that time, where skin color matters in society, can be the reason behind this choice.

5.2.1.1 Characteristics of the study area

Land is unique in terms of immobility and inhomogeneity (Whipple, 1995). The location is fixed, situated immobilely in a particular area; and at the same time, no two plots are entirely identical. Investigating the characteristics of the study area is essential to avoid misleading conclusions about the influencing factors, which may arise from relying solely on a review of previous studies. The review may have a scientific basis, but it still has a chance to fail to capture the locality and specificity of the study area.

Our valuation area is shown in Figure 57:

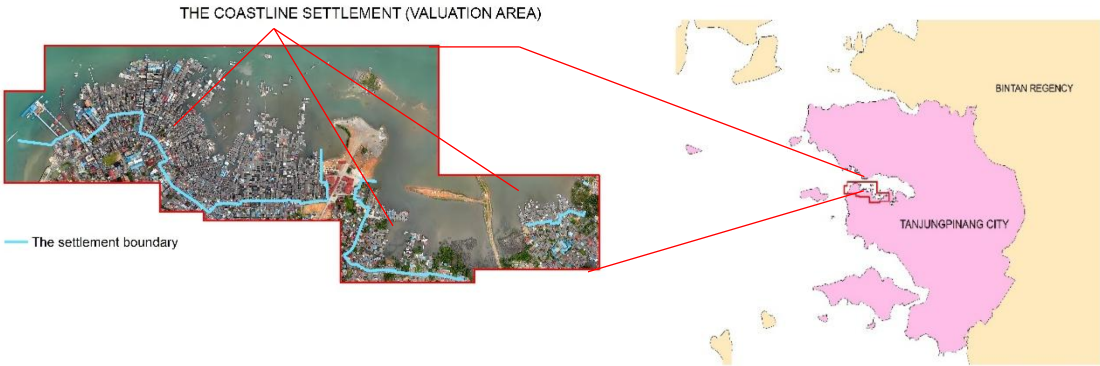


Figure 57. Study area for land valuation

The investigation of the local characteristics also follows the categorization from Eckert, Gloudemans, and Almy (1990).

a. Economic characteristics.

   The study area, which today consists of three villages (Kelurahan Tanjungpinang Kota, Kamboja, and Tanjung Unggat), is the oldest settlement in Tanjungpinang City. A couple of Chinese merchants founded it in the 17th century. The local predicate for the area is "Kampung Tua" or Old Village. Since 1784, the area has been served as a "bandar", or seaport, that has been known for its loading services of goods and materials, besides fishing and fishery in the Malayan Peninsula. Most of the residents rely on fishery activities as anglers or in sectors related to fishery affairs (i.e., as shopkeepers, carriers, fish-processing factory laborers, fish delivery drivers, shipping company workers, and ship repair and maintenance workers). Fishery commodities are the biggest commodity, with 46.7% of the total market share for all traded commodities in Tanjungpinang (BPS Tanjungpinang, 2015). Because fishery affairs drive the economy, the land market in the area is inevitably influenced by the presence of some related infrastructure, such as a fish market as a business center, ports, and jetties.

b. Social characteristics.

   There is no social exclusion or discrimination that influences the land market in the area. The sellers and buyers may come from any ethnic group or social class. Furthermore, unlike in some neighboring coastline settlements in the Tanjungpinang area, such as the Pulau Penyengat or Kelam Pagi settlement, the settlement does not show a communal system of land occupation that restricts land transfer and affects the land market. From the cultural aspect, although the Chinese's view about way of living and housing luck might have been influential a few decades ago, nowadays it has been left by most of the actors in the land market.

c. Characteristics from law, government, and political situation.
   - With regard to the conformity to spatial planning or zoning bylaws in coastal areas, generally the conformity of the housing areas should be viewed towards:
     - Protected and reserved areas (e.g., conservation zone, forests, and heritage zone)
     - Navigational zone/shipping line
     - Port areas
     - Prone areas for hazards and disasters
     - Open green space
     - Other zones that are restricted to residential buildings, such as governmental and military zone.

     From our investigation, the study area is zoned for residential, trade and service, and reclamation purposes on RTRW of Tanjungpinang City. The area is not located in any prohibited zones mentioned earlier. Hence, we concluded that the aspect of conformity to spatial planning has been fulfilled, and our research will not use this factor to model land value because its feedback will be uniform to the model.
   - In our study area, where the heterogeneity of tenure forms is apparent, the property occupation status in the area exists in two types. First, the properties lack legal proof documents. Mostly, the properties of this status are vacant lands or informally leased buildings. Second, the properties have a legal document, which can be a contractual lease document or a letter (SKT, or Letter to Prove the Possession) given by the village administration.

d. Characteristics based on physical, environmental, and location
   - One unique characteristic of the coastline settlement is having two modes of transport: road and water transport, either for people or for goods delivery (cargo). According to the locals, the settlement is called pemukiman pelantar, so the roads there are also called jalan pelantar ("pelantar roads"). Despite being called roads, actually most of pelantar roads are still in the form of bridges, erected above the water surface. Some road segments are already hardened with concrete and coated with asphalt ("asphalt roads"). Some are already concreted but not yet asphalted ("concrete roads"), and a few are still made of wood ("wooden roads"). The pelantar roads, following a classification from Law No. 22 of 2009 on Transport and Traffic, can be categorized into collector roads, local streets, and neighborhood streets. The city's public land transportation does not serve the settlement, so the locals make use of their own vehicles for their mobility. Water transport is made by personal boats that pass through the outlet in-between the buildings or through public transportation that serves some ports along the settlement. In total, there are 14 ports in the area; 11 of them are jetties.
   - There is a difference in depth across the settlement. The depth will increase gradually from the land to the sea, following the slope. The deepest position is in the outermost part of the settlement. The more it juts into the sea, the closer the access to the sea, but on the contrary, the farther the access to the land.
   - The buildings are not floating but piled, stilted structures with foundations that reach the water bottom. Most of them are single-family houses, not condominiums or multi-family housing. This type of property is classified as real property (IAAO, 2013).
   - From field observation, no historical record of big-impact coastal hazards caused by natural sources was ever found in the study area. The changing tidal wave as well as slow-onset disasters, according to Saputra et al. (2021) in their research in Semarang Coastal Areas, is not convincing as the affecting factor of land prices.

- In the matter of road connectivity, the properties in the settlement can be classified into the properties with road connection (“road-connected properties“ or “direct-access properties”) and the properties without road connection, i.e., the accessibility is made through a connection from another building (“indirect-access properties”) or by water only (“water-locked properties“).
- The settlement is a long-standing residential area with a variety of property sizes and road frontages. The buildings were established at different times following the city’s growth. This also leads to variations in the condition of the buildings. Thus, logically, in the process of buying and selling properties, a depreciation of buildings matters. This situation is in contrast to a newly built settlement, where depreciation normally does not necessarily apply.

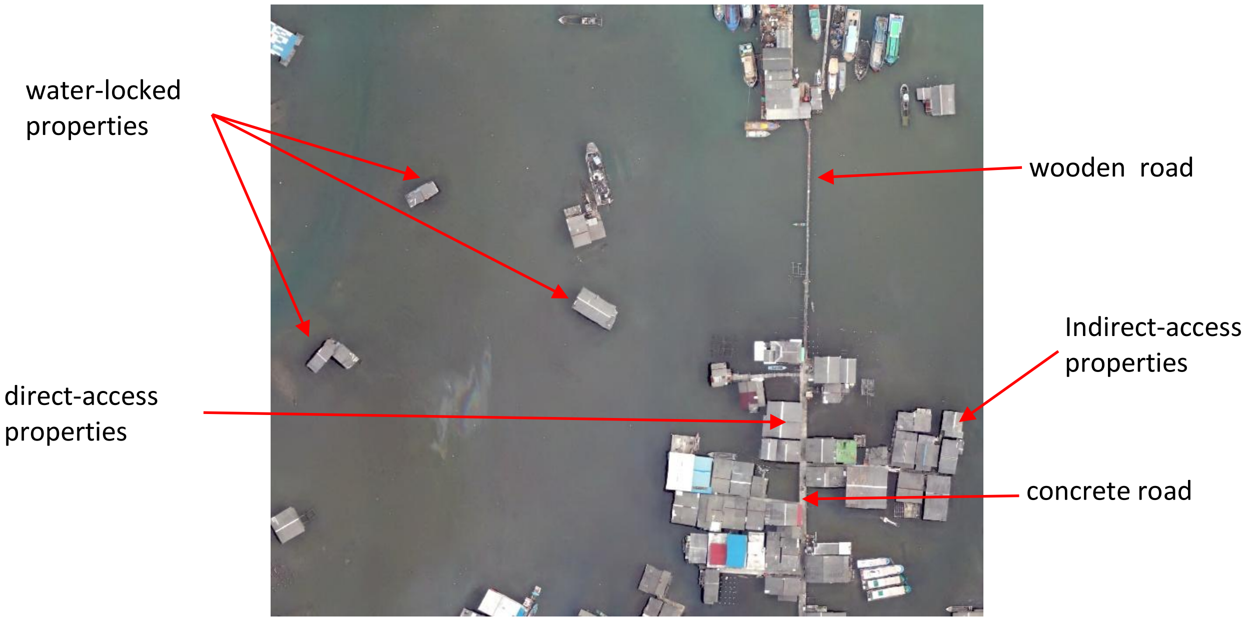


Figure 58. Type of properties in coastline settlements

- From the field observation, it is known that clean water and electricity are distributed evenly in the settlement. Drainage, gas, and fixed-line telephones remain unavailable. This uniform situation made us unable to incorporate the factors related to the availability of utilities.
- The use of land in the study area is multifarious. Most plots are vacant lands or already in the built-up area for houses and *ruko* (or shophouses: mixed-use buildings, mostly two or three stories high, with a shop on the ground floor for mercantile activity and a residence above the shop). There are no public facilities, such as hospitals and schools, in the coastline area or its nearby surroundings that can be assumed to influence the local land market. A small number of the plots are used for worship places (mosques and temples), port buildings, shipping warehouses, hotels, swiftlet nests, and restaurants. Not all properties are saleable in the land market, for example, mosques and temples. The others are saleable and therefore have a market value, or, in other words, can be used in valuation modeling.

5.2.1.2 Data: affecting factors

After knowing the rationale from the previous studies and the characteristics of the study area, we selected 17 affecting factors from all groups. The selected factors are only the ones considered relevant. There is no factor from the social group. Table 42 shows those factors.

Table 42. The affecting factors

Economic (1)	Social (2)	Law, government, and politics (3)	Physical, Environment, Location		
			Physical (4)	Environment (5)	Location (6)
▪ Date of property transfer[1,a,**] ▪ Property price [1,b,**] ▪ Interest rates [1,b,**]		▪ Tenure status [1,a,**]	▪ Property use [1,a,*] ▪ Depth [2,b,*] ▪ Building age [1,b,**] ▪ Size of property [1,a,*] ▪ Building quality [1,b,**] ▪ Frontage [1,b,*] ▪ Road functional class [1,b,*]	▪ Sea view [2,b,*]	▪ Distance to central fish market [2,*] ▪ Distance to land [2,b,*] ▪ Distance to nearest port [2,b,*] ▪ Access of road [1,b,*] ▪ Access of waterway [2,b,*]

Information:

[1] = common factors for residential area valuation
[2] = distinctive factors which only apply for such settlements
[a] = cadastral factors
[b] = non-cadastral factors
** = spatial factors*
*** = non-spatial factors*

We obtained the factors' datasets from the UAV orthophoto, field surveys, and Tanjungpinang Land Office records. The operational definition, descriptions, and the process for transforming those datasets into ready-to-use variables for the modeling process are described below.

1. Date of property transfer (“dt_transf”).
   A date of property transfer is a date when the transfer of a property occurs from one party to another. The date can be the date of transaction, the date of sale, the date of mortgage, or the date of contract. The letter No. 55/PJ.6/1999 from the General Director of Taxation stipulated that the date of transfer is not supposed to be more than 5 years before the valuation year (Directorate General of Taxation, 1999). Property transfer data from 2014 to 2017 was utilized in this study. Since mass appraisals typically set the valuation date to January 1st of the valuation year, property prices need to be adjusted to reflect the time between the transfer and valuation dates. In this research, the valuation date is January 1st, 2018. We adopted a formula from the letter to get the percentage of date correction. The formula is as follows:

$$PI = \frac{(dv - dt)}{365} * ir \quad \text{(eq. 48)}$$

   Where:
   PI = percentage of price increase
   dv = date of valuation
   dt = date of transfer
   ir = interest rate

2. Property price (“pr_price”).
   A property price is the market price of a property in a monetary system. The price data appears in the form of transaction, sale, and contract prices. Research often only uses transaction prices and sale prices. In this research, we also used contract prices to achieve a representative

number of samples in the modeling process. The data were taken from a field survey and from Tanjungpinang Land Office records. We only considered transfer prices from 2014 to 2017, as stated in Number 1 regarding the date of property transfer.

a. Transaction price or purchase price.

   A transaction price is the deal price based on an agreement between the seller and the buyer. The price is an actual price reflecting the ideal property price, and therefore there is no need for a correction.

b. Sale price or offer price.

   A sale price is the price offered by the seller. This price is usually broadcast higher than the actual price of the transaction. Thus, a correction is necessary. In this research, we used a 10% correction to get close to the actual price, following the recommendation by BPN (2014). A calculation to get the actual price from the sale price is:

$$Property\ price = sale\ price * 90\% \quad \text{(eq. 49)}$$

c. Contract price.

   A contract price is the price of property leasing. In a normal land market, the contract price per year is anticipated at 5% to 10% of the actual price, depending on the type of property (Filbert, 2014). The percentage is known as the property's yield. Vacant plots have a yield ranging from 0,5% to 2,5%; houses are from 3% to 5%; and shophouses are from 6.5% to 9%. This research took the highest yield percentage, meaning 2.5% for vacant plots, 5% for houses, and 9% for shophouses. To get close to the actual price, we use the calculation below:

$$Property\ price = \frac{contract\ price\ per\ year}{yield} \quad \text{(eq. 50)}$$

3. Interest rate ("rate").

   An interest rate is the amount of interest due per period published by the Bank of Indonesia, the country's central bank. We used the average rate from 2014-2017 to adjust the property price increase per year, which is 6,4%.

4. Property use ("pr_use").

   Property use shows what kind of use the land or the buildings make. Because this research is about the valuation of residential areas, to achieve a fair market value, the properties whose utilization is commercial (shophouses, restaurants, swiftlet nest buildings, hotels) should be adjusted. Following Letter No. 55/PJ.6/1999 from the General Director of Taxation (Directorate General of Taxation, 1999), we used a 25% reduction of the property price.

5. The factors related to building depreciation.

   a. Building age ("bd_age").

      Building age is the effective age at the time of the valuation. In the research, as shown in Table 43, we use the maximum building age of 50 years as a threshold. For a practical purpose, the effective age of the building was calculated from the last renovation, except for the ones that have never been renovated (which is very unlikely to occur) and from the construction year. According to a regulation from the Indonesian Minister of Public Works No. 24/PRT/M/2008 about Maintenance and Treatment of Buildings (Kemen PU, 2008), renovation means a significant improvement by fixing the big damage to the building with the intention to regain the functions that might be similar or improved in terms of the structure, architecture, and utilities. Renovation differs from rehabilitation, as rehabilitation only repairs the small or medium damage to the building. To calculate the building's effective age, we deployed a calculation from BPN (2014) as follows:

$$BEA = valuation\ year - construction\ or\ renovation\ year \quad \text{(eq 51)}$$

b. Building condition ("bd_cond").
Building condition is the condition of the building, seen from its structures, components, and facilities. We categorized the conditions into five categories from BPN (2014): very good (VG), good (G), average (A), bad (B), and very bad (VB).

Building age and building condition factors play a role as inputs for determining building depreciation. The rate of depreciation is derived from a table provided by BPN (2014).

Table 43. Building depreciation rate

Building age	Depreciation rate (in %) according to building condition				
	VG	G	A	B	VB
0	0	0	0	0	0
1	3	4	5	6	7
2	5	7	9	11	11
3	7	10	13	16	16
4	10	13	17	20	21
5	12	16	20	24	27
6	14	19	23	28	31
7	15	22	26	31	35
8	15	24	29	34	38
9	15	26	32	37	43
10	15	28	35	40	47
11	15	30	38	43	50
12	15	32	40	46	53
13	15	32	42	49	56
14	15	32	44	52	58
15	15	32	46	54	60
16	15	32	48	56	63
17	15	32	50	58	65
18	15	32	50	60	67
19	15	32	50	62	69
20	15	32	50	64	71
21	15	32	50	66	73
22	15	32	50	67	75
23	15	32	50	67	76
24	15	32	50	67	77
25	15	32	50	67	78
26	15	32	50	67	79
27	15	32	50	67	80
28	15	32	50	67	80
29	15	32	50	67	80

Table 43 (continued)

30	15	32	50	67	80
31	15	32	50	67	80
32	15	32	50	67	80
33	15	32	50	67	80
34	15	32	50	67	80
35	15	32	50	67	80
36	15	32	50	67	80
37	15	32	50	67	80
38	15	32	50	67	80
39	15	32	50	67	80
40	15	32	50	67	80
41	15	32	50	67	80
42	15	32	50	67	80
43	15	32	50	67	80
44	15	32	50	67	80
45	15	32	50	67	80
46	15	32	50	67	80
47	15	32	50	67	80
48	15	32	50	67	80
49	15	32	50	67	80
50	15	32	50	67	80

Explanation of building condition (BPN, 2014):

VG : Structures, components, and facilities are in perfect state
G : Structures and components are no damage, several facilities less function
A : Structures are no damage, damage on some components and facilities
B : Structures are in small damaged, damage to most components and facilities
VB : Structures, components, and facilities are in damaged condition

6. Tenure status (te_status).
   Tenure status is defined as the tenure status of a property occupation. The status affects the property price. In a normal market-value, the ideal property is one that has formal and legalized proof of occupation. The transfer of a property without proof is considered to not deliver the actual market price, and the price is usually lower than its ideal price. Therefore, the property price must be adjusted. The letter No. 55/PJ.6/1999 from the General Director of Taxation stipulated that the adjustment is about 10–30% of the transfer price. In this research, we used 10% correction for the property without a proof of occupation and 0% correction (i.e., no correction) for the one with a proof of occupation.

7. Size of property ("size").
   The size of a property is the area of a property in square meters. We calculated two datasets concerning the size: the size of the land and the size of the building.

8. Depth ("depth").
   Depths are the vertical distance from the water's bottom to the building's floor (illustrated by Figure 59).

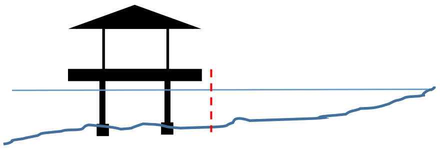


Figure 59. Illustration of depth

The depth can be considered as the affecting factor of land value in the coastline settlements because it is associated with construction costs and the risks borne by the settlers. The deeper the water, the higher the construction costs and risks due to tidal influences, currents, and waves. In his research, Firdaus, Jaya, and Apdillah (2013) explain that the threats to the area and other coasts in Tanjungpinang might come from a north wind, a natural occurrence that strikes the coastal area from November to February every year. We deployed a direct measurement using a measuring bar to obtain the depth at certain points (i.e., measurement points) near the properties. In total, we measured 60 points. Then, get all the depth values for the whole area, using GIS, we converted the data into a raster by making an interpolation. Finally, we extracted the depth value of each property from the resulting raster. Figure 60 shows the map on depth information.

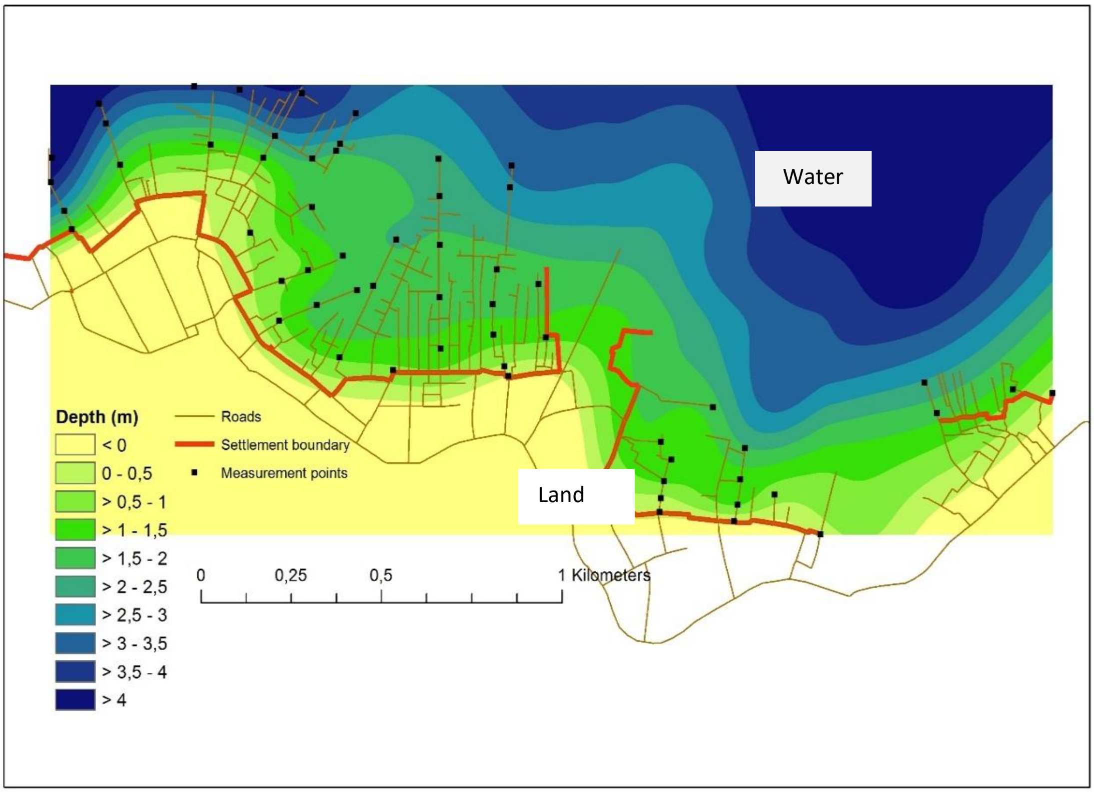


Figure 60. Raster interpolation contains depth information

9. Road functional-class ("road_cl").
The road functional class is a variable showing the class based on the functionality and capacity categories of the nearest roads to the properties. As has been identified before in Section Characteristics of the Study Area, in the settlement there are three types of roads: collector roads, local streets, and neighborhood streets. The collector roads are low-to-moderate-capacity roads that serve to move traffic from the local streets to arterial roads and are

designed to provide access to residential areas. All the collector roads are asphalted, which makes them the best quality for mobility and accessibility for the occupants in terms of safety and amenity. The local streets are roads that provide access inside the area and have a lower carrying capacity than the collector roads; almost all of these roads have been concreted. The neighborhood streets are branches of the local streets and have the lowest carrying capacity. Small wooden roads, alleys, and pedestrian streets belong to the neighborhood streets. In this study, we assigned a score of 3 to collector roads, a score of 2 to local streets, and a score of 1 to neighborhood streets. The road layer was delineated from the UAV orthophoto produced before, and the road name was collected from a field survey. Figure 61 depicts the road network in the study area.

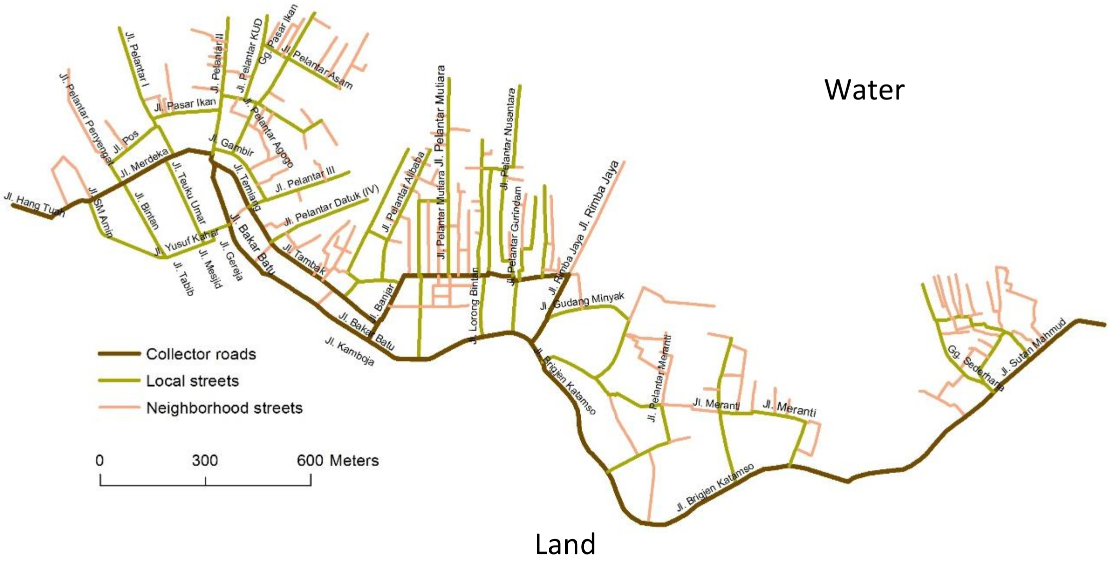


Figure 61. Road network in the study area

10. Sea view ("se_view").
    Sea view is an amenity variable showing how the view is towards the water. This variable is categorical, where score 1 represents the properties with a water view and score 0 is for the properties that have no water view.
11. Variables related to distance.
    a. Distance to central fish market (di_markt).
       Distance to the central fish market is a variable that shows the shortest route from the property centroid to the central fish market as the central business district (CBD). The market is located on Jalan Pelantar KUD.
    b. Distance to nearest port (di_port).
       Distance to the nearest port is a variable that shows the shortest route from the property centroid to the nearest port.
    c. Distance to land (di_land).
       Distance to land is a variable that shows the shortest route from the property centroid to the settlement boundary that separates the coastline settlement from the mainland.

Some notice in this distance measurement:

- The centroid was created by GIS.

- The route distance was measured by implementing road network modeling that finds the shortest path in the ArcGIS geodatabase (see Figure 62).
- If the property has two adjacent roads, we took the road situated right in front of the property or the one with a higher level than the other one.

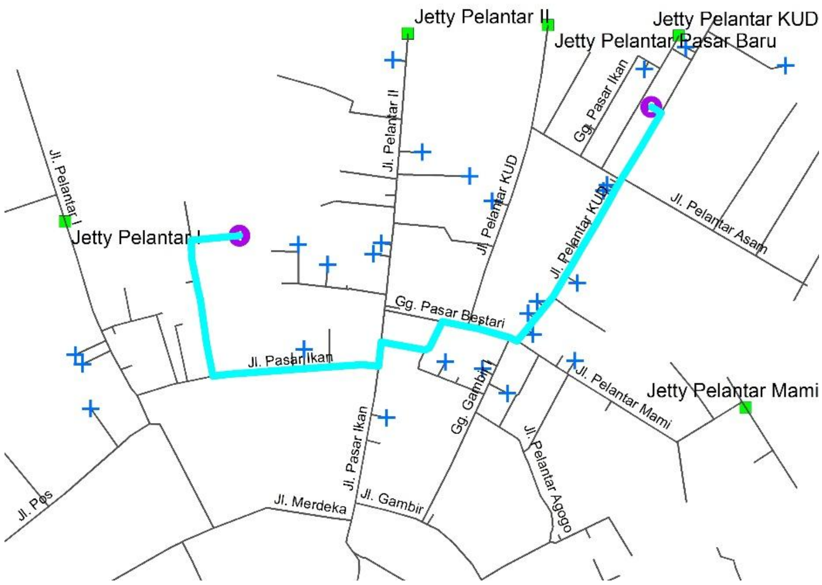


Figure 62. Example of distance measurement

12. Variables related to access availability.
    a. Access to road ("ac_road").
    Access to roads is a variable that shows the connectivity of the properties to the roads. We assigned a score of 1 to properties that have direct access to the road (i.e., direct-access properties). Score 0 was assigned to the property that has no direct access (i.e., indirect-access properties or water-locked properties).
    b. Access to waterway ("ac_water").
    A waterway is a body of water serving as a route or a channel for vessels (i.e., a navigable body of water). Access to the waterway is a variable that shows whether the properties have a waterway. Score 1 was assigned to the property that has a waterway, while score 0 is for the property that has no water access.

13. Frontage ("frontage")
    Frontage is the length of the property's front side that faces directly onto the road (see Figure 63). Frontage, measured in meters, was determined from the UAV orthophoto using GIS. As the water-locked properties and indirect-access properties do not have a real road frontage, we assigned a value of 0,90 meters (equal to the normal size of the entrance or door of houses in the area).

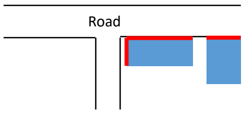


Figure 63. Illustration of frontage

Table 44. Valuation variables

No	Factors	Role	Abbreviation (variable name used in the modeling) and unit
1	Property price	Factors to build the dependent variable: "Land Value"	la_value (IDR/m^2)
2	Interest rates		
3	Date of sale/transaction		
4	Property use		
5	Tenure status		
6	Building age		
7	Building quality		
8	Size of property		
9	Depth	Independent variables	depth (m)
10	Distance to central fish market		di_markt (m)
11	Distance to land		di_land (m)
12	Distance to nearest port		di_port (m)
13	Frontage		Front (m)
14	Sea view		se_view
15	Road functional class*		road_cl-local
			road_cl-collector
16	Access to road		ac_road
17	Access to waterway		ac_water

* Road functional class factor is an ordinal variable with three categories or levels. To use the regression algorithm for correctly analyzing attribute variables and logical interpretation of the result, this variable should be split into k-1 binary dummy variables; k here means the number of categories. As a result, with the neighborhood category as a reference, we will create two dummy variables, road_cl-local and road_cl-collector. The first is a dummy variable for local streets, and the latter is a dummy for collector roads.

Adjustment process

To reflect ideal market conditions, an adjustment was made in the formation of the dependent variable (la_value). The adjustment applied to property price, date of transfer, property use, building depreciation, tenure status, and valuation date factors. The adjustment flow can be viewed in Appendix 8.

In this research, we focused solely on land value and exclude building value. Building value was derived from a depreciation calculation, which requires Replacement Cost New (RCN) data. RCN was obtained by multiplying the building area by the cost of constructing a new building per meter. New construction costs in this research were obtained from developers in Tanjungpinang. The construction costs for a new building were categorized based on building type, as shown in the following Table 45.

Table 45. Building cost

BUILDING COST PER METER SQUARE			
No	**Building type**	**Number of floor**	**Price (IDR)**
1	Houses	1	1.500.000
		2	2.000.000
		3	2.500.000
2	Shophouses	1	2.000.000
		2	2.500.000
		3	3.000.000

5.2.2 Sampling method

There are two common methods for selecting samples for mass land valuation in Indonesia. The first is a random-based approach, also known as accidental sampling, which aims to gather a sufficient number of samples from the area to develop a valuation model. The only limitations are related to data suitability, such as the absence of outliers. This sampling method is most effective in regions with a vibrant and active land market, such as newly developed areas, where obtaining data on land prices is relatively easy.

The land market in our study area was not very active—20 to 40 transactions on average per year—so a second sampling method, called stratified random sampling, was used to build the model that explains land value. The study followed a rule of thumb from Green (1991) and (Tabachnick & Fidell, 1989), which stated that in order to avoid overfitting (the resulted model is too complex for the data — happens when the sample size is too small), in double regression analysis the number of samples required is $n > 50 + 8m$, where n is the minimum number of the needed samples and m is the amount of independent variables.

Following that formula, then with 9 independent variables:

$$n > 50 + 8m$$
$$n > 50 + 8*9$$
$$n > 50 + 72$$
$$n > 122$$

In this thesis, the samples were obtained from property price data for 2014-2017. In total we obtained 172 samples. It is recommended to secure a representative number of samples based on the margin of error and the desired level of confidence. This aligns with the provisions of the BPN (2014) which states that for the evaluation and updating of land values, for non-agricultural areas (such as residential area, industrial land, commercial land, and vacant land), at least 30 samples are required, regardless of quotas per land use type. This is because the characteristics of non-agricultural land use in Indonesia are highly heterogeneous and tend to be unclustered.

Even though the availability of samples depends a lot on the number of transactions, offers, or contracts happening on the land market at any given time, we tried to collect samples from all over the area so that each region was fairly represented in this thesis (see Figure 64).

Figure 64. Sample distribution

5.2.3 Parcel-based mass valuation: result and testing

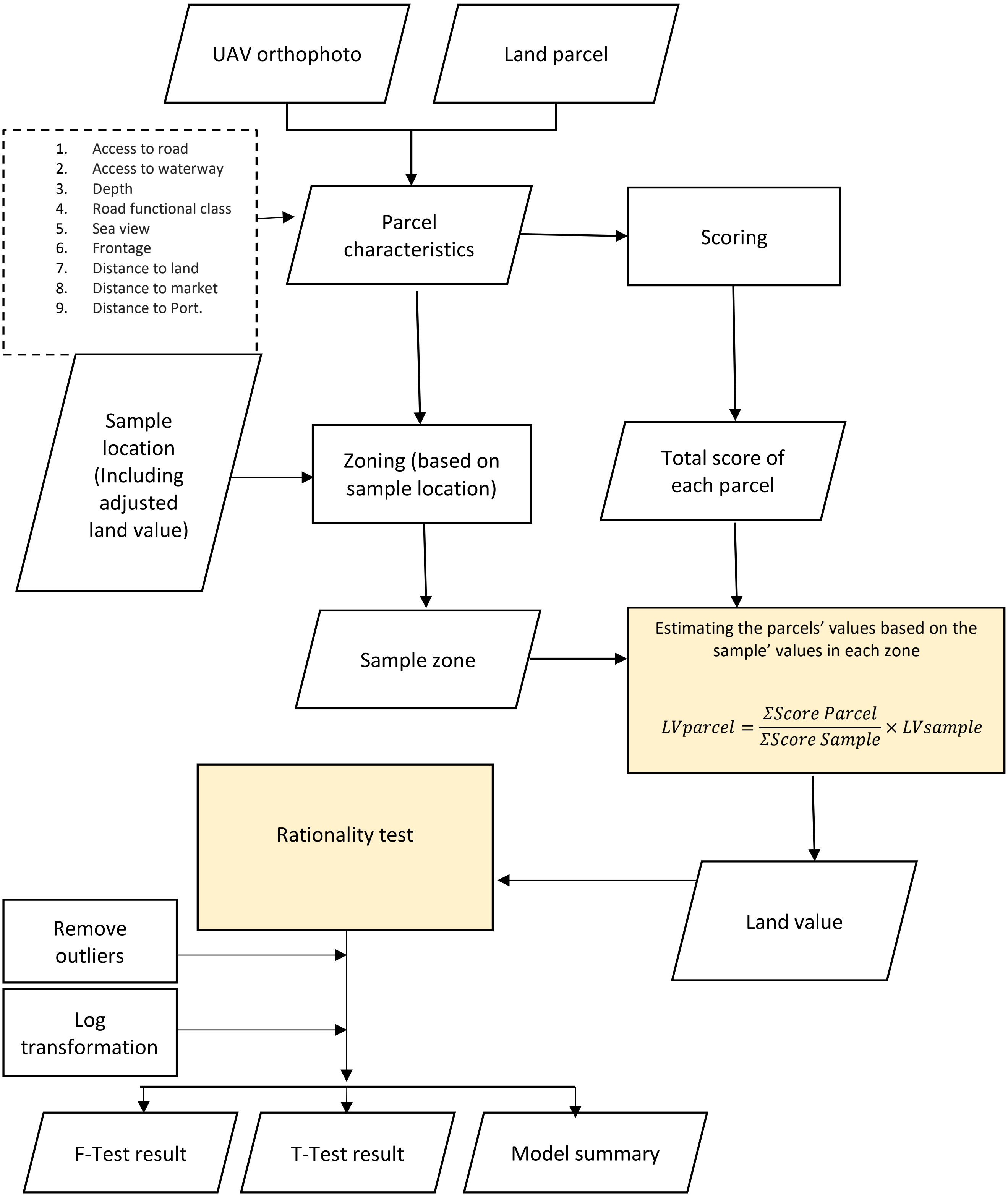


Figure 65. Flow of valuation

Figure 65 depicts the flowchart of the valuation process in this study.

5.2.3.1 Land value map production

To conduct the valuation, below are the steps taken:

a. Preparation of base map.
The base map for value is the orthophoto from the previous result. The orthophoto serves as a reference for integrating all the geodatasets used in the valuation process.

b. Preparation of land parcel map.
The land parcel map is the same as the reference map used in the analysis in previous chapters. This map was generated through on-screen digitization of the orthophoto.

c. Attributing the parcel with scores.
We assigned scores for each class of the nine independent variables—access to roads, access to waterways, depth, road functional class, sea view, frontage, distance to land, distance to the market, and distance to the port—to the land parcel's spatial layer. Scoring is predicated on the reasoning behind how particular factors affect land value. When a class of a variable goes up in a way that logically raises land value, it gets a higher score, and vice versa. Appendix 9 lists the score of every class of the variables.

d. Creation of preliminary zones.
Given that each sample is spread across different parts of the research area, to provide spatial context and avoid bias in the land value that could result from the diverse sample variations, it is necessary to categorize land parcels into preliminary zones. The zones are just the working zones and will not representing the final zones in the result map later. In this study, zoning was approached using Thiessen polygons based on the sample locations (Figure 66). Thiessen polygons, also referred to as Voronoi polygons, divides a geographical space into several zones where each point within a zone is closer to a specific sample point than to any other sample points (Weisstein in William & Hartomo, 2021). Thus, each Thiessen polygon represents the area of influence or dominance of the sample point located at the zone. The parcel in the area was evaluated based on the characteristics and influence of the nearest sample, which helps in generating more accurate and fair land values, avoiding the bias that could arise from the diverse sample variations.

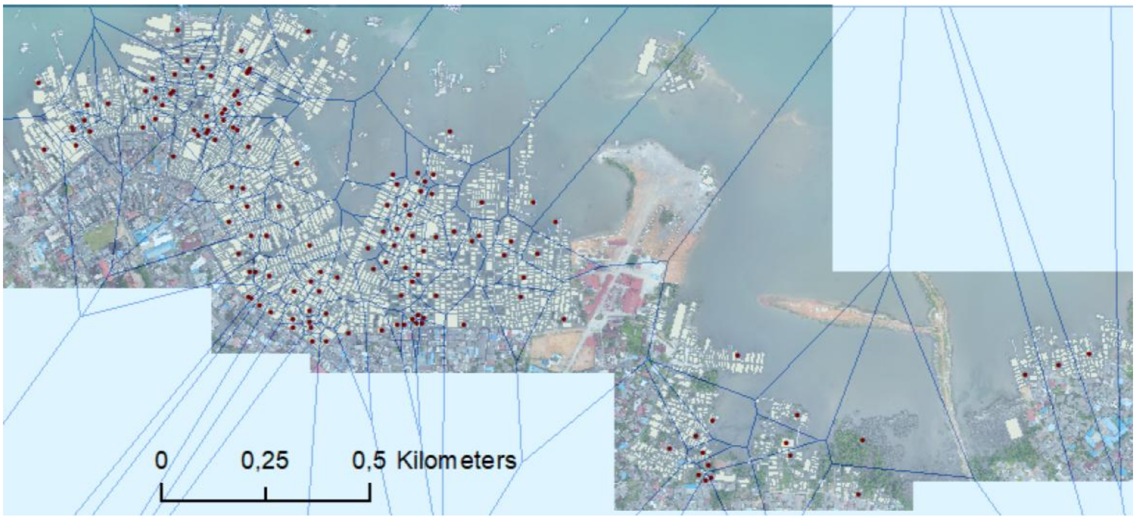


Figure 66. Thiessen polygon

e. Estimating the land parcel values based on the sample values within each zone.
The estimation was done computationally with a formula as follows:

$$LV_B = \frac{\Sigma Score_B}{\Sigma Score_A} \chi \, LV_A \qquad \text{(eq. 52)}$$

LV_B = the estimated land value of Parcel B (the target parcel).
LV_A = the known land value of Parcel A (a reference/sample parcel).
$\Sigma Score_A$ = Total score of Parcel A, which is derived from the sum of its characteristics scores

$\Sigma Score_B$ = Total Score of Land Parcel B, which is derived from the sum of its characteristics scores

This formula estimates the land value of a neighboring parcel (LV_B) based on a reference parcel (LV_A) using a ratio of their respective total scores. (LV_A) is derived from the land prices that have been adjusted into land values. If a zone contains multiple samples, the closest sample to the target was used. This approach assumes that the relationship between land values and parcel characteristics is proportional. If Parcel B has a higher total score than Parcel A, its estimated land value (LV_B) will be greater than the sample value (LV_A) and vice versa.

Table 46 and Figure 67 shows result of the estimation after classifying it into eight classes, following the symbology from BPN (2014).

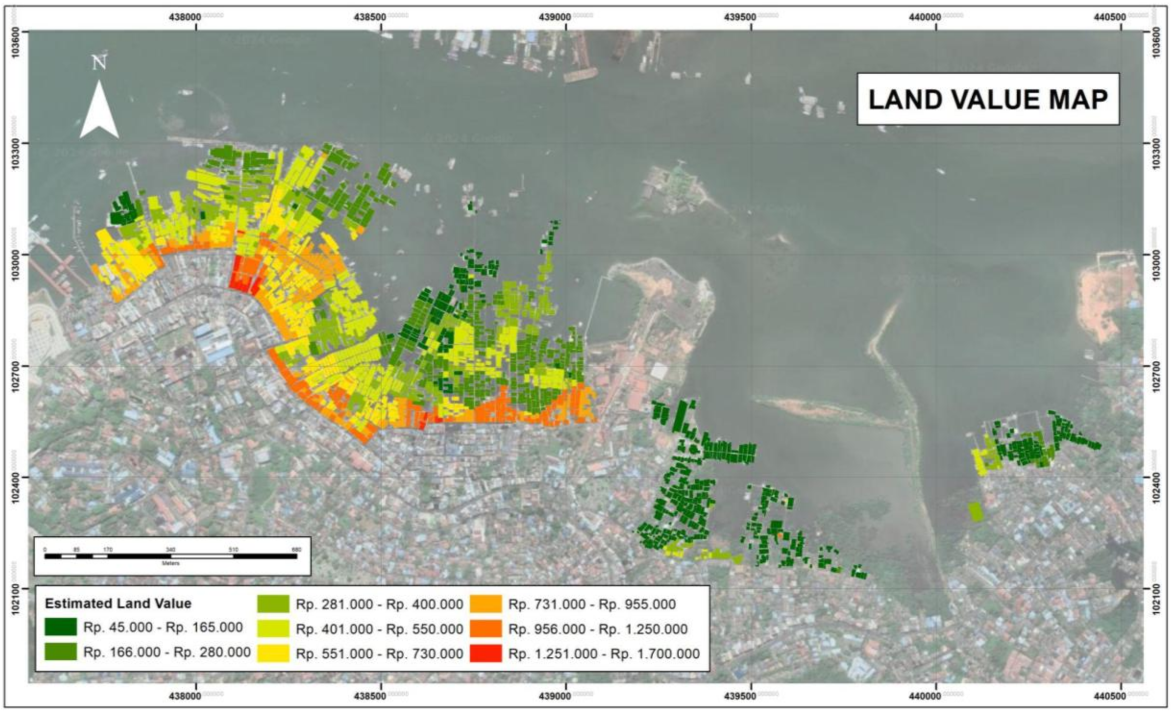


Figure 67. Land value map

Table 46. Calculation of land value

No	Class	Number of Sample	Estimated Land Value (IDR)	Average (IDR)	Number of Parcel	Total Area (m2)
1	A	30	Rp45.000 - Rp165.000	Rp109.373	535	74.224,92
2	B	24	Rp166.000 - Rp280.000	Rp233.137	467	68.088,5
3	C	19	Rp281.000 - Rp400.000	Rp362.289	378	56.502,12
4	D	35	Rp401.000 - Rp550.000	Rp473.201	515	79.860,16
5	E	19	Rp551.000 - Rp730.000	Rp712.568	331	48.393,78
6	F	20	Rp731.000 - Rp955.000	Rp872.999	302	35.844,54
7	G	22	Rp956.000 - Rp1.250.000	Rp1.096.699	273	31.878,51
8	H	3	Rp1.251.000 - Rp1.700.000	Rp1.503.601	61	3.948,82

5.2.3.2 Rationality test

To evaluate the rationality between independent variables and the estimated land parcel values as dependent variables, the Multiple Linear Regression equation model is used:

$$Y = \beta 0 + \beta 1X + \beta 1X + ... + \beta 9X9 + \varepsilon \qquad \text{(eq. 53)}$$

Y = Estimated land parcel value
β0 = *Intercept*
β1-9 = Regression Coefficients for variables X1-X9
X1-9 = Sequentially road class, access to road, access to waterway, sea view, distance to market, distance to port, distance to land, depth, frontage

To achieve optimal results, the optimization was conducted by removing samples with studentized residuals greater than the absolute value of 2. In regression analysis, studentized residuals were used to identify outliers. These residuals were calculated by dividing the residual by an estimate of its standard deviation, adjusted for the influence of each observation on the regression model (Cook, 1979). Thresholds such as 2, 3, and 3.3 were used to determine outliers, with 2 being a more conservative choice to ensure safety in identifying influential data points.

A land valuation linear model can also be created using transformations on its variables (either the dependent variable or the independent variables). A common transformation used for land values is the logarithm due to the clarity of the regression model interpretation. This means that the model is not linear in its variables but remains linear in its parameters, thereby maintaining the principles of linear regression (Graybill and Iyer, 1994). A model without transformation has the advantage of using raw data without any alterations, making the resulting model more reflective of actual reality.

Interpretation is also clearer. On the other hand, changing variables has the benefit of better meeting statistical criteria because it can often resolve common problems like different units of measurement and data distributions that are not normal. Variable transformation techniques are among the methods used to tackle such problems. Below is the model using log transformation.

$$\ln Y = \beta 0 + \beta 1X + \beta 1X + ... + \beta 9X9 + \varepsilon \quad \text{(eq. 54)}$$

ln Y = Estimated land parcel value
β0 = Intercept
β1-9 = Regression Coefficients for variables X1-X9
X1-9 = Sequentially road class, access to road, access to waterway, sea view, distance to market, distance to port, distance to land, depth, frontage

Below is the model performance result using F-test (Table 47) and T-test (Table 48)

Table 47. Result of F-test

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1008,151	9	112,017	766,390	,000[b]
	Residual	352,103	2409	,146		
	Total	1360,254	2418			

a. Dependent Variable: ln_landvalue

b. Predictors: (Constant), front, se_view, di_land, di_markt, road_cl, di_port, ac_water, depth, ac_road

The F-test was used to assess the overall significance of the valuation model by evaluating whether the explanatory variables collectively have a significant impact on the dependent variable. This test helps confirm that the model is not based on random noise but on factors that meaningfully influence land value. Based on the ANOVA results, there is a significant finding with an F value of 766.390 and significance p < ,0001. This indicates that the regression model as a whole makes a significant contribution to the variation in the dependent variable.

Table 48. Result of t-test

Coefficients[a]

Model		Unstandardized Coefficients B	Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	7,826	,113		68,972	,000
	ac_road	-,122	,042	-,068	-2,910	,004
	ac_water	,009	,025	,005	,339	,735
	road_cl	,074	,008	,131	8,948	,000
	se_view	-,057	,030	-,025	-1,937	,053
	di_port	,071	,011	,095	6,741	,000
	di_markt	,567	,010	,683	54,438	,000
	di_land	,258	,013	,330	19,135	,000
	depth	,247	,014	,277	17,674	,000
	front	,085	,032	,056	2,672	,008

a. Dependent Variable: ln_landvalue

The t-test was applied to evaluate the significance of each individual variable within the model. It helps determine whether each factor significantly contributes to the valuation. In the t-test, the unstandardized coefficients (B) represent the effect size of each independent variable on the dependent variable (ln_landvalue), while the standardized coefficients (Beta) allow for comparison across variables by standardizing the scales. Significant t-values (with $p < 0,05$) indicate that the corresponding independent variable has a statistically significant impact on the dependent variable. The t-test criteria states that a variable is considered significant if Sig. < α (0,05) and the t-value is greater than the t-statistic or less than the negative t-statistic.

- ac_road: This variable has a significant negative coefficient, indicating that an increase in access to roads is associated with a decrease in land value.
- road_cl: This variable, likely representing distance to a main road, has a significant positive coefficient. This indicates that land parcels closer to main roads tend to have higher values.
- di_port: Distance to the port has a significant positive coefficient, indicating that land closer to the port tends to have higher value. This might seem counterintuitive, but it could be due to factors like increased noise and traffic.
- di_markt: Distance to the market has a highly significant positive coefficient, suggesting that proximity to markets is a major driver of land value.
- di_land: This variable has a significant positive coefficient, indicating that proximity to the mainland can positively influence land value.
- depth: Depth has a significant positive coefficient, suggesting that proximity from the water surface to waterfloor can positively influence land value.
- front: This variable has a significant positive coefficient, indicating that properties with greater frontage tend to have higher values.
- ac_water variable is statistically insignificant (meaning that these variables do not have a partial effect on land value).
- se_view is marginally insignificant, as it is close to 0,05.

Table 49. Model summary

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.861[a]	.741	.740	.38231

a. Predictors: (Constant), front, se_view, di_land, di_markt, road_cl, di_port, ac_water, depth, ac_road

The model summary (Table 49) provides an overview of the regression model's performance. The summary can be explained as below:

1. R (0,861) shows the multiple correlation coefficient, which indicates the strength of the relationship between the independent variables (predictors) and the dependent variable. A value of 0,861 suggests a strong positive correlation.
2. R^2 (0,741) reflects the coefficient of determination, this value represents the proportion of variance in the dependent variable that is explained by the independent variables. 74,1% of the variance in the dependent variable is explained by the model, which is quite high.
3. Adjusted R^2 (0,740): This adjusts the R^2 value based on the number of predictors in the model, preventing overestimation when more variables are included. The fact that Adjusted R^2 is very close to R^2 (0,740 vs. 0,741) suggests that the predictors are relevant and contribute meaningfully to the model.
4. Std. Error of the Estimate (0,38231): This is the standard deviation of the residuals (errors). A smaller value indicates better model accuracy. It suggests how much the actual values differ from the predicted values on average.

This regression model explains a significant portion (74,1%) of the variance in the dependent variable. The F-statistic is 7660.390 with p-value < 0,001 (Sig. = ,000). This indicates the model as a whole is statistically significant. The strong R value indicates a strong relationship between the predictors and the outcome variable. The small difference between R2 and adjusted R2 suggests the model is well-fitted without unnecessary predictors (a good model fits without overfitting). Although from the t-test we find 2 insignificant variables (ac_water and se_view) and 1 counterintuitive variable (ac_road), we still keep them with some considerations, such as the strong R-value, these predictors are conceptually important and help explain the multifaceted nature of land value, they might have low statistical significance in some areas but high economic or policy relevance in specific locations, and as shown by this thesis by using score-comparison technique, land valuation model in this thesis is not purely statistical-based. Also, when we tried to analysed futher by removing the unsignificant, having collinearity issue, and counterintuitive factors, the results shows no difference, even the R^2 slightly decrease from 7,41 to 7,40 (Appendix 10). Therefore, in this thesis, we opt to use all predictors in the estimation process to maintain its explanatory power.

5.3 Investigation of UAV-based survey system and GIS to support land valuation

Data was acquired via field surveys and orthophotos. Data obtained from field surveys can consist of both primary data (property use, building age, and condition) and secondary data (data on property transfers, property prices, interest rates, tenure status, and property size) from Tanjungpinang Land Office records. Field surveys also produced depth data through a measuring bar. The depth will then be further processed with GIS. The orthophoto served as the material for GIS to extract spatial characteristics such as road functional class, sea view, distance to certain points, access availability, and frontage. From just one orthophoto, we can obtain 8 spatial data, showcasing the adaptive capability of UAVs in supporting fit-for-purpose land valuation in coastline areas. The orthophoto enables time- and cost-effective data acquisition. Obtaining spatial data, for example frontage, does not require individual building surveys. Its high accuracy and versatility are particularly valuable for aquatic land valuation.

GIS is central to this aquatic land valuation study. The characteristics of each variable in this research are extracted by GIS modules from the orthophoto, such as:

- *Interpolation* feature to obtain characteristic depth in the area.
- *Network Analysis - Closest Facility* feature to obtain distance to point of interest.
- *Near* feature to obtain the closest road functional class in each building.
- *Select and Field Calculator* feature to determine buildings with sea view, access to road, and access to waterway.

Using GIS, we are able to assign score and calculate land value on a mass scale. The result is visualized with color gradation representing land value of each parcel. Data visualization in maps are easily understandable by stakeholders and facilitate informed decision-making. GIS has demonstrated its ability to support a fit-for-purpose land valuation.

6 DISCUSSION, CONCLUSION, AND RECOMMENDATIONS

This chapter is dedicated to delivering a general summary of the research. Discussion brings retrospection of this study with regard to providing definite land information. To extend the discussion, this chapter reviews the strengths, weaknesses, opportunities, and threats (SWOT) qualitatively of what this study has proposed to the existing system in the context of tenure arrangement, the cadastral system, and land valuation. The conclusion part confirms the research exploration and results toward the stated objectives of this research. Recommendation delivers specific actions or strategies and potential future research and development based on the findings of the study.

6.1 DISCUSSION: PROVISION OF FIT-FOR-PURPOSE LAND INFORMATION

6.1.1 Retrospection

The essential idea of this study is to provide fit-for-purpose land information to increase tenure security in aquatic land settlements. Fit-for-purpose land information refers to the terms that include, but are not limited to, certain, contextualized, purpose-oriented, and legally-recognized data about land parcels, encompassing various aspects such as ownership, boundaries, use, value, and other relevant attributes. This information is critical for establishing contextual tenure, facilitating effective land management, economic development, and environmental protection, and aims to boost social stability with the ultimate goal of supporting sustainable development. In the aspect of tenure, clear and recognized land information provides legal protection to landowners and users, reducing the risk of disputes and unlawful evictions. Besides that, well-defined and compliant boundary and ownership data help in resolving land disputes efficiently.

In sustainable planning, effective land information supports informed decision-making for land use planning. Accurate data and information support optimal allocation of resources and infrastructure. In the aspect of economic development, the provision of formalized land value would increase investment confidence and enable access to credit as the owner can use their legalized property as collateral for a loan. Definite land information in coastal areas also contributes to environmental protection, as detailed land information helps in identifying and mitigating risks such as erosion (i.e., disaster preparedness). In a social aspect, especially from a social stability perspective, we can look at community empowerment (i.e., providing communities with clear land information empowers them to assert their rights and participate in land use decisions) and equitable development (i.e., ensuring that all land rights, including customary and traditional rights, are documented and respected).

Table 50 describes the land-related information this study provides and its supported aspects:

Table 50. Aspects supported by land-related information

No	Land-related information	Supported aspects				
		Tenure development	Effective land management	Economic development	Environmental protection	Social stability
1	Proper tenure forms, both statutory and non-statutory	✓	✓		✓	✓
2	Coastal planning zones	✓	✓		✓	
3	Eligible subjects/parties	✓		✓		✓
4	Tenure placement boundary	✓	✓		✓	
5	Suitable use	✓	✓	✓	✓	✓
6	Rights (entitlement)	✓	✓	✓	✓	✓
7	Restrictions	✓	✓	✓	✓	✓
8	Responsibilities	✓	✓	✓	✓	✓
9	Base map (UAV orthophotos)	✓	✓		✓	
10	Thematic layer derived from UAV orthophotos	✓	✓		✓	
11	Proper cadastral objects	✓	✓		✓	✓
12	Definite boundary	✓	✓		✓	✓
13	Physical cadastral data: location, dimension	✓	✓		✓	✓
14	Accuracy metadata	✓	✓			
15	Land value per parcel			✓	✓	✓
16	Land value zone		✓	✓	✓	✓

Source: author's analysis

6.1.2 Discussion of strengths, weaknesses, opportunities, and threats

To discuss the SWOT of what we have been conducting in supporting tenure security in coastline settlement, in order to give a clear perspective, we first divide tenure arrangements, cadastral system, and land valuation into several elements before we explore each element one by one, as listed in Table 51.

Table 51. Aspect and element to review using SWOT approach

No	Aspect	Element to discuss
1	Tenure arrangement	Usage of statutory and non-statutory rights
		Consideration of local preferences
		Usage of spatial planning zones as controllers of land allocation
		Tenure allocation that complies to both land-based and coastal marine-based regulations
		Usage of AHP and Fuzzy TOPSIS to look for the optimum tenure form for people in the coastline area
2	Cadastral system	Building footprints as built-up parcel boundaries
		Usage of UAV as a survey system and orthophoto as a cadastral base map
		Usage of semi-automatic boundary extraction
3	Land valuation	Usage of value factors from physical-environtal, economic, social, based on the coastline settlement characteristics
		Usage of parcel-based mass valuation

6.1.2.1 SWOT of tenure arrangement:

Usage of both statutory and non-statutory rights

The use of both statutory and non-statutory has advantages to create a more integrated and adaptive framework that respects both legal and customary practices, potentially leading to inclusive land tenure management. Statutory rights provide a formal and legally enforceable framework for tenure arrangements. Under this formalization, the statutory framework supports formal land ownership, which can increase property values and attract investment. Having non-statutory rights, often rooted in local customs and practices, allows for flexibility and adaptability to local conditions and needs. This can lead to more culturally appropriate and accepted land use practices. Non-statutory rights enable better integration of local community practices and preferences into land tenure arrangements, promoting local acceptance and cooperation. Unfortunately, the coexistence of statutory and non-statutory rights also has weaknesses; there may be inconsistencies in how both tenure forms are applied or interpreted. Managing a system that incorporates both rights requires effective coordination between various administrative bodies, which can be challenging. The coexistence of different rights offers a chance to develop adaptive policies that better address local conditions and evolving challenges in coastal areas. Although, there could be a threat in managing a dual system of rights that can lead to bureaucratic inefficiencies and delays in decision-making. Statutory and non-statutory rights bring their own set of strengths and weaknesses. While statutory rights offer legal clarity and formalization, non-statutory rights provide flexibility and local adaptation. The main challenge is also related to administrative complexity.

Consideration of local preferences

Incorporating local preferences in land tenure arrangements in the coastal areas of Tanjungpinang City provides a range of benefits, including increased community buy-in, cultural relevance, and fine-tuned solutions. However, it also presents challenges such as complex negotiations. Opportunities lie in developing innovative tenure models and empowering communities. Understanding and integrating local preferences can lead to the development of innovative and adaptive tenure models that better address local issues. Threats include conflicting interests, resistance to change.

Usage of spatial planning zones as controllers of land allocation

By designating different areas for specific purposes like residential, commercial, or conservation, spatial planning zones provide a structured approach to land use and aid in organized development. For example, the RTRW and RZWP3K stipulate the cleared zone for disaster mitigation. According to Law No. 24 of 2007 concerning Disaster Management Article 32, the government has the authority to set the disaster zones as the forbidden areas for settlements. Although it can also bring inflexibility because spatial planning zones can be rigid. The zones may not easily accommodate changes in land use or emerging needs, potentially leading to outdated or ineffective land management. By complying with spatial planning zones, efficient allocation would be achieved. Zoning facilitates the effective distribution of resources and infrastructure; zoning quarantee the development of areas in line with their intended purpose. Threats might rise as economic pressures and demands for development may conflict with zoning regulations, potentially leading to unauthorized changes in land use.

Tenure allocation that complies with both land-based and coastal marine-based regulations

Regulation-compliant tenure allocation seeks the situation that the allocations adhere to legal and regulatory frameworks. This is very important to avoid future law problems. For example, ones must comply the Ministry of ATR/BPN regulation (i.e., Minister of ATR/Head of BPN Regulation No. 17 of 2016 Article 5) that formal land rights are only can be given to the aquatic land parcels that have been already built with buildings. This regulatory basis provides a clear legal framework for land and resource use and has flexibility by allowing adaptive management practices customized to local conditions and can accommodate a variety of land uses and stakeholder needs. Regulatory compliance often includes provisions for environmental conservation. In the other side, regulatory processes can be cumbersome and slow and usually navigating the legal framework can be challenging for stakeholders. Compliance to regulations bring opportunity to strengthen governance and institutional capacity for coastal management although political corruption can undermine the integrity of tenure allocation processes.

Usage of AHP and Fuzzy TOPSIS to look for the optimum tenure forms

Using AHP and Fuzzy TOPSIS for determining the optimal tenure form in coastal areas offers a structured approach. AHP (Analytic Hierarchy Process) provides hierarchical framework to evaluate multiple criteria and alternatives, facilitating systematic comparison and prioritization. Fuzzy TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) handles uncertainty and vagueness in decision-making, improving the accuracy of evaluations by incorporating subjective judgments. A combination of used quantitative data with qualitative assessment, providing a more nuanced understanding of the potential tenure forms. These methods make sound decision-making by considering multiple criteria and stakeholder inputs. AHP and Fuzzy TOPSIS incorporate input from various stakeholders, ensuring that multiple perspectives are considered. However, they require significant resources, expertise, and accurate data, and may face challenges from stakeholder conflicts of interest. The methods' complexity and reliance on subjective assessment can also introduce biases. Also, it has to be noticed that, coastal management involves interactions with other systems (e.g., marine, terrestrial, social), and the methods may not fully capture these complexity. Overall, while AHP and Fuzzy TOPSIS provide valuable insight, their application must be carefully managed to address potential limitations and obtain effective outcomes.

The summary of the analysis is presented in Table 52.

Table 52. Summary of the SWOT analysis of tenure arrangement

No	Element	SWOT			
		S	W	O	T
1	Usage of both statutory and non-statutory rights	▪ Legal clarity and structure ▪ Flexibility and adaptability	▪ Coordination issues	▪ Integration ▪ Local engagement ▪ Policy innovation ▪ Conflict mitigation	▪ Administrative inefficiencies/ bureucratic hurdle
2	Consideration of local preferences when establish proper land tenure forms	▪ Community buy-in ▪ Cultural relevance ▪ Adapted solutions	▪ Diverse preferences ▪ Uneven benefits	▪ More local engagement ▪ Innovative tenure models ▪ Improved management	▪ Cultural resistance
3	Usage of spatial planning zones as controllers of land allocation	▪ Orderly land use ▪ Environmental protection ▪ Clear guidelines ▪ Regulatory framework	▪ Rigidity/ Inflexibility ▪ Administrative burden	▪ Efficient allocation and planning	▪ Regulatory gaps ▪ Economic pressures ▪ Opposition
4	Tenure allocation that complies with both land-based and coastal marine-based regulations	▪ Legal clarity ▪ Environmental protection transparent and enforceable ▪ Integrates different regulatory frameworks	▪ Coordination issues ▪ Cost of compliance	▪ Coordinated governance ▪ More access to funding and support	▪ Political instability ▪ Cumbersome and slow
5	Usage of AHP and Fuzzy TOPSIS to look for the optimum tenure forms for people in the coastline area	▪ Structured decision-making ▪ Inclusive process ▪ Quantitative and qualitative integration	▪ Accuracy of input data and subjectivity ▪ Model limitations (simplification of complex issues)	▪ Decision support (improved tenure options and scenario analysis) ▪ Informed policies ▪ Dynamic adjustments ▪ Clear rationale	▪ Data variability ▪ Complex interactions

6.1.2.2 SWOT of UAV-based cadastral system

Usage of UAV as cadastral survey system and orthophoto as a cadastral base map

Using UAVs for cadastral surveys and orthophotos as cadastral base maps is in line with the spatial framework of fit for purpose approach. UAVs offer significant advantages in terms of high accuracy, detailed imagery, efficiency, and cost-effectiveness. UAVs can quickly cover large areas, reducing the time and cost compared to traditional methods, while providing real-time data and the ability to operate in various terrains. This technology improves data collection with capabilities like multispectral imaging and 3D mapping, making it a versatile tool for detailed and current cadastral information. However, the approach faces challenges such as regulatory and legal issues (e.g., flight height restriction: *Stated in Ministry of Transport Regulation No. 37 of 2020, maximum operation altitudes is up to 400 feet (120 meters), flying higher than 120 meters requires approval from the regulator*), privacy concerns, dependency on weather conditions, battery limitations, and the need for specialized training and significant initial investment. Data management challenges arise from the fact that integrating UAV data with existing cadastral systems and ensuring compatibility can be complex.

Opportunities for this technology include improvements in UAVs and software, as well as the development of supportive policies and international standards. UAVs has opportunity to engage with stakeholders (e.g., landowners, government agencies) to improve survey processes and outcomes. However, there are also threats from regulatory hurdles, equipment malfunctions, and adverse weather. Stringent regulations and airspace restrictions could limit UAV operations and increase compliance costs. Weather conditions can disrupt UAV operations and affect the quality of data collected. Economic instability and market fluctuations could impact the affordability and availability of UAVs technology. To fully leverage the benefits and address the risks, careful management is essential for effective implementation of UAV-based cadastral surveys.

Building footprints as built-up parcel boundaries

Using building footprints as land parcel boundaries in coastal settlements offers clear and precise property demarcation. This approach helps optimize space, simplifies land registration and taxation, and aids in creating accurate maps. However, it has significant drawbacks, including vulnerability to environmental changes, which can alter building footprints and impact boundary stability. Additionally, defining parcels strictly by buildings may limit flexibility in land use and zoning and can lead to overcrowding and infrastructure strain. Defining parcels strictly by building footprints can limit flexibility in land use, such as expansion or redevelopment. This type of boundary may also create challenges in adhering to zoning regulations and land use plans, especially if buildings are nonconforming.

This approach allows resilient infrastructure investments through better property management. Clear boundaries improve property legal clarity, protecting homeowners and investors. However, environmental hazards, legal and regulatory compliance issues, and economic factors like property value fluctuations and higher insurance costs pose threats. Building damage from frequent natural disasters can cause boundary disputes. In vulnerable coastal areas, changing building codes and environmental regulations can be difficult to comply with. Environmental risks and market dynamics affect coastal property values.

Usage of semi-automatic boundary extraction

Semi-automatic boundary extraction on orthophotos offers notable strengths such as increased efficiency and speed. OBIA considers both spectral and spatial information, potentially leading to more accurate boundary extraction compared to pixel-based methods. Automation reduces manual labor and human error. Mapflow.AI that integrates with QGIS shows seamless workflow, meaning the direct integration with QGIS allows for a smooth and cohesive workflow. The integration of advanced algorithms and human oversight add precision. Because QGIS is open-source software, this process can significantly reduce costs compared to proprietary GIS software. Using Mapflow.AI from QGIS also denotes to institutional framework from fit-for-purpose approach that priotizes a more flexible ICT approach rather than high-end technology solutions. However, this study notices that the method has its weaknesses, including the complexity of initial setup and a significant learning curve for users. The accuracy of boundary extraction is heavily reliant on the quality and resolution of orthophotos, with factors like shadows and varying illumination are affecting performance. The method struggles with complex or irregular boundaries, such as in dense area in the south part of the AOI (near the city center) limiting its flexibility and requiring more manual intervention in certain scenarios. The method also deliver specific use cases, meaning not all geographic features may be suitable for semi-automatic extraction, limiting its applicability.

Opportunities for improvement and expansion are abundant, particularly through technological like machine learning and cloud computing. Despite these opportunities, there are threats such as technological challenges and data privacy concerns that need to be addressed to fully realize the potential of semi-automatic boundary extraction on orthophotos. Dependence on software tools may pose a risk if they are not regularly updated or maintained, especially for open source software. Table 53 summarizes the result of the analysis.

Table 53. Summary of the SWOT analysis of cadastral system

No	Element	SWOT			
		S	W	O	T
1	Building footprints as built-up parcel boundaries	▪ Clear demarcation (definite boundaries and ease of identification) ▪ Efficient land use (maximized space) ▪ Simplified administration (streamlined processes and ease of mapping)	▪ Vulnerability to environmental changes ▪ Limited flexibility (restricted land use and zoning issues) ▪ Potential for overcrowding (density issues)	▪ Certain property management ▪ Resource optimization	▪ Environmental hazards ▪ Legal and regulatory challenges (compliance issue and boundary disputes) ▪ Economic factors (property value fluctuations and insurance and liability)
2	Usage of UAV as cadastral survey system and orthophoto as a cadastral base map	▪ High accuracy and detailed imagery ▪ Efficiency and cost-effectiveness ▪ Flexibility and accessibility (versatily and real-time data) ▪ Speed data collection	▪ Regulatory and legal issues (privacy concerns) ▪ Technical limitations (weather dependency and battery life) ▪ Data management challenges (large data sets and integration issues) ▪ Initial investment (cost of equipment dan training requirement)	▪ Technological advancements (improved UAV technology and software development) ▪ Expanded applications ▪ Policy and regulation evolution (international standards) ▪ Community engagement	▪ Regulatory hurdles (restrictive regulations and changing policies) ▪ Technological risks (cybersecurity threats and equipment failure) ▪ Environmental factors (adverse weather)

Table 53 (continued)

3	Usage of semi-automatic boundary extraction	▪ Efficiency and speed ▪ Human oversight ▪ Cost-effective	▪ Complexity ▪ Dependence on image quality ▪ Limited flexibility (algorithm limitations and specific use case)	▪ Technological advancements ▪ Support decision-making	▪ Technological challenges (software reliability) ▪ Data privacy and security

6.1.2.3 SWOT analysis for land valuation

Usage of value factors from physical-environtal, economic, social, based on the coastline settlement characteristics

By incorporating diverse factors (access to roads and waterways, depth, road functional class, sea view, frontage, and proximity to land, markets, and ports), this method provides a holistic view of land value, aiding in informed decision-making and leads to a more accurate reflection of true land value, reducing the risk of overvaluation or undervaluation. The multi-dimensional analysis helps land value estimates responsive to market conditions

However, this approach faces resource intensity of data collection for big scale valuation and the potential for subjectivity and bias in weighting different factors. Inconsistencies in data quality (especially from respondent data) and availability may affect the accuracy of the valuation. Although we have already anticipated by conducting previous comparative analyses from other studies, there is a potential for bias in selecting and prioritizing factors, leading to skewed results. Despite these situations, we also notice that GIS and remote sensing can improve the efficiency, accuracy, and consistency of the data process, especially ini spatial data acquisition techniques such as for acquiring data about location, depth, and distance. The use of large datasets can raise concerns about data privacy and security, potentially leading to regulatory challenges.

Usage of the comparison score technique of parcel-based mass valuation

Parcel-based mass valuation provides notable advantages in terms of efficiency and cost-effectiveness for large-scale property assessment. This approach can be implemented accurately and efficiently using computer-assisted valuation techniques. The process is transparent, offering stakeholders a clear and auditable method of valuation. Additionally, statistical rationality tests are employed to verify the accuracy of valuations by identifying outliers and inconsistencies, thereby increasing the reliability of assessment. However, the effectiveness of parcel-based mass valuation is highly dependent on the quality and completeness of the data. Inaccurate or outdated data can lead to erroneous valuations. Furthermore, maintaining current data and algorithms can be resource-intensive. A key benefit of parcel-based mass valuation is that it establishes the boundaries of value zones align precisely with parcel boundaries. This alignment prevents appraisal confusion and eliminates the issue of a single parcel being divided across multiple value zones, a situation that complicates the assignment of land taxes and transaction tariffs.

Despite these challenges, there are significant opportunities for improvement and expansion. Technological development of AI and machine learning can help to increase accuracy and efficiency. However, threats such as economic volatility and regulatory challenges, must be addressed. The result of this study in one-time value that comes from one periode of survey. Then, it should be noticed that economic instability and market fluctuations can influence the economic factors, leading to unpredictable changes in land value. It should be anticipated as well that sudden changes in policies related to land use, zoning, and environmental protection can affect land value estimates. Successfully navigating these issues is crucial for add the benefits of this method. The summary of the analysis is provided in Table 54.

Table 54. Summary of the SWOT analysis of land valuation

No	Element	SWOT			
		S	W	O	T
1	Usage of value factors from physical-environtal, economic, social, based on the coastline settlement characteristics	▪ Comprehensive valuation ▪ More accurate reflection of true land value	▪ Complexity ▪ Data quality ▪ Subjectivity in valuation	▪ Community engagement	▪ Data privacy
2	Comparison-score method in parcel-based mass valuation	▪ Can be done simply with a computer (computer assisted valuation) ▪ Mathematical model and formula are relatively easy to comprehend ▪ Rationality tests help in verifying the accuracy of valuations ▪ Consistent between samples value and estimated value ▪ Clear and auditable valuation method ▪ Cost-effective, as using samples eliminates the need for field surveys of all parcels	▪ Could resource intensive ▪ Data dependence ▪ Simple math model would potentially make certain details are missed. ▪ Require outlier elimination	▪ Technological advancements ▪ Replicable to other sites	▪ Economic volatility (market fluctuations and development pressures) ▪ Regulatory and policy challenges ▪ Data and attributing process is highly crucial ▪ Dynamic of data cut-off ▪ Missing future impacting factors (e.g., port development planning)

6.1.3 Limitations and restrictions

This research project encounters challenges and is limited to some degree by restrictions. This study identifies the key limitations following on the objectives and their corresponding approaches and methods.

In **Objective 1**, which aims to discover proper tenure arrangements, the limitation is related to data characteristics and methodological constraints. RTRW, one of the spatial plans utilized in this study, serves as a general spatial plan for policy operational guidelines. Thus, the conformity level of tenure toward spatial plans is also just appearing at a general level. In the methodology aspect, the AHP multi-criteria analysis approach, through its pairwise comparisons, could only consider a limited number of variables due to its cognitive complexity. For conformity and tenure applicability analysis, this study uses heuristic evaluation.

Objective 2. In assessing the utilization of the UAV system to generate a boundary through a semi-automatic segmentation method, the main challenge is field characteristics. The survey using a UAV-fixed wing is limited in flexibility due to regulatory restrictions on flight operations near airports and military installations and is subject to airspace regulations that impose certain rules on flight altitude and flight paths. Furthermore, the dense urban environment in our study area poses a significant concern. Light reflections and diffusion from building surfaces distort the images. Relevant features, such as building edges or rooftops, may be difficult to resolve due to the overlap or similarity in structure and texture among buildings. As a consequence, the visual quality of the produced orthophoto in very dense areas is affected.

Building footprint extraction using semi-automatic feature detection, OBIA and Mapflow.AI, face challenges and struggles in complex urban environments with dense building clusters or irregular shapes. Distinguishing individual buildings in tightly packed urban areas is a difficult task, especially when they share similar textures or colors. OBIA typically segments an image based on object characteristics (e.g., texture, color, shape), but, given that buildings vary widely in design, materials, and structural features, the process does not always conform to a predictable pattern. This inevitably affects the quality of edge detection.

In fulfilling **Objective 3** to develop and assess the valuation model for aquatic land settlement, the study is hindered by insufficiently recent data. The study area exhibits a relatively inactive land market with an average of only 20-40 transactions per year. During the valuation phase, to meet the minimum sample requirement, the dataset was extended to include transactions up to four years prior. Older transaction data may not adequately reflect current market conditions, and hence, it should be noted that the result is compromised. The inability to validate the hedonic valuation model using ground truth data was a limitation of this study due to the lack of available samples. Another limitation is the simplification. The continuous variables are also scored following the classes. It is also noticed that the Thiessen polygons, which are used to indicate preliminary zones, only assume that the influence boundary of each transaction sample is determined by distance. Although Thiessen polygons produced a result that each land area was evaluated based on the characteristics and the influence of the nearest sample, it does not account for spatial factors such as natural or man-made (roads, for example) for making preliminary zones.

6.2 CONCLUSION

This section presents a conclusive summary of how the research objectives and questions have been addressed through the study's findings.

6.2.1 Findings from Ojective 1 on tenure arrangements

This thesis denotes that its 1st objective is

To discover proper tenure arrangement by searching the optimum tenure forms and examining their compliance with spatial plans and physical settings

Below are the summaries of results.

6.2.1.1 Types of secure situation prefered by the locals

What secure situation is preferred by the local?
We had finished our study regarding that matter as presented in Chapter 3. From the literature study, we found 6 criteria and 18 subcriteria of tenure situations: *duration* (3 subcriteria), *recognition* (4 subcriteria), *security* (2 subcriteria), *accessibility and opportunity* (3 subcriteria), *convenience in using land* (5 subcriteria), and *convenience in transferring land* (3 subcriteria) that matter for the locals. Our further analysis using field interviews and decision-support tools to find

the most preferred ones gave results that the subcriteria from *duration* criteria, *unlimited time of occupation*, which means having the ability to occupy land indefinitely, is becoming the highest priority for secure land tenure. Then, a *recognition* subcriteria: *administrative recognition in a residence card or other administrative documents* is also considered crucial by the locals and becomes the second preferred situation. It is followed by *no fear of/minimum/no evictions and land expropriation* taken from *security* criteria, *easier access to get developmental supports/aid*, and *convenience to use the land for housing* as the top five secure tenure situations. This top five situation denotes that stability of tenure and accessibility to take advantage of its stability are central. Table 55 presents our answer to the first question from the first objective, presenting those 18 secure tenure situations in table format.

Table 55. List of secure situation preferred by the locals

Preferred secure situation (subcriteria/criteria)	Ranking
Unlimited time of occupation/Duration	1
Administrative recognition in a residence card or other administration documents/Recognition	2
No fear of/minimum/no evictions and land expropriation/Security	3
Easier access to get developmental supports/aid (e.g., electricity, clean water, road infrastructure, public buildings, fishing facilities, etc.) from the government/other institutions/ Accessibility and opportunity	4
Convenience to use the land for housing/ Convenience in using land	5
Recognition in the legal documents of the land (e.g., certificates, permits, deeds, contracts) by the tenure authoritative bodies/ Recognition	6
Convenience of inheritance/ Convenience in transferring land	7
Convenience to use the land for various type of usage/ Convenience in using land	8
No fear of/minimum/no of potential disputes/ Security	9
Recognition by neighborhoods/ Recognition	10
Higher possibility to access credit from bank/financial institutions/Accessibility and opportunity	11
Convenience in transactions with Indonesian/ Convenience in transferring land	12
Higher prices in transactions and compensation/ Accessibility and opportunity	13
Convenience to use the land for aquaculture activities/ Convenience in using land	14
Long period of occupation and usage (>10 to until the maximum period allowed by the regulations)/ Duration	15
Convenience to use the land for commercials buildings/ Convenience in using land	16
Short period of occupation and usage (max 10 years)/ Duration	17
Convenience in transactions with foreigners/ Convenience in transferring land	18

This study discovers that the *convenience of transferring land* is not a priority, proven by its subcriteria that get only middle and low rankings. It is also found that *short-term occupation* and *transactions with foreigners* are becoming the two least preferred situations. Those previously mentioned situations exhibit the tendency of the locals to consider land as a place for stable living rather than an economic asset that can be easily traded and transferred. In conclusion, this study shows that *long duration*, *formal recognition*, *no evictions*, *easy access to support, convenience of housing*, and *inheritance easiness* are important secure situations desired by the locals.

6.2.1.2 Potentially applicable statutory and non statutory foms

What statutory and non-statutory tenure forms are potentially applicable to be implement?
To answer this question, we investigated various regulations from various ministries/government agencies/local administrations to find the type of tenure and conducted field observations to search for potential statutory and non-statutory tenure forms for aquatic land parcels in the study area.

This study managed to identify 11 potentially applicable tenure forms, consisting of six formal statutory and five non-statutory forms. The main difference of those tenures, aside from the source and the issuing sector, is related to the type of tenure. The ones from land-based regulation is in the format of Rights, the SWK is in the form of Contract, and the IP/IL and SPI are in the form of Permit. We identified three tenure forms from land-based regulations, one from housing and settlement regulation, and two from coastal and marine regulations. From land-based regulation, it is found that Right of Use (HP) and Right to Build (HGB) which focus on the entitlement rights of the holders to use the land for certain purposes in a specific duration, are relevant to be implemented together with Communal Rights (HK), a type of formal land rights that give privilege to communities (a group of people) as a single entity or potential subject of the land. The tenure form for the housing sector is "leasehold tenure" or SWK (sewa kontrak) which provides an opportunity for tenants to physically use and occupy a property in certain periods of time and conditions under a legal contract made in public notary. IL/IP is a permit given by the authorities to occupy the space of the coastal waters and small islands and to manage and exploit coastal and small islands' resources for specific purposes stipulated by law. SPI is a permit issed by Riau Island local goverments for individuals or fishing companies to occupy and utilize a certain area in coastal waters for fisheries activities such as breeding, spawning, and aqua-culture cultivation.

We also discovered five non-statutory forms from traditional practices, historical precedents from the Malay Sultanate and Dutch colonial era, old local administration, and local customs. These forms exist in the communities. The first one is Numpang Bangun (NB). NB is a system of landholding where the community allocates land to a member for free housing purposes, based on either an oral or written agreement. The GR (Grant) letter is a letter from the colonial era and is considered to give power to the holder to claim the land. Surat Tebas is an old statement paper given by the hamlet (small village) head that denotes permission to the member of the village (usually in the size of two hectares) to access and clear the land (for example, shore vegetation) for certain purposes including fishery activities and erect buildings. SWBT system is landholding type similar to SWK but the agreement is all informal without any formal agreement on a legal basis. The last one, SKT is a generic name for a statement letter from the head of the village showing that an individual whose name written in the letter is the person who has right to occupy the land.

All those listed and selected tenure forms reflect the continuum of tenure; that tenure can take various formats, from oral agreement, letter/contract, permit, and rights. Table 56 presents our answer to the 2nd question from the first objective, presenting those 11 potentially applicable/suitable tenure forms.

Table 56. List of potential tenure forms

No	Name of tenure forms	Category	Source of tenure
1	HP	Statutory	BAL 1960 (Land administration and derivative regulations)
2	HGB		
3	HK		
4	SWK		Housing and settlement regulation
5	IL/IP		Spatial planning regulations Coastal marine regulations
6	SPI		
7	NB system	Non-statutory	Traditional
8	GR (Grant)		Malay Sultanate and Dutch colonial era
9	ST		Old local administration
10	SWBT system		Local customs
11	SKT		Local administration

6.2.1.3 Optimum tenure forms

What are the optimum tenure forms, ranked as the trade-off between the preferred secure situation and the potentially applicable tenure forms?

This study answers the question using AHP and Fuzzy TOPSIS analysis in trading the situation and the tenure forms off. AHP was used to gain weights or the importance level of the subcriteria. Fuzzy TOPSIS aims to evaluate the chosen alternatives (i.e., the potential tenure forms) with input from AHP weights. The ranking shows the level of the most optimum to the least optimum, arranged from the weights taken from Fuzzy TOPSIS calculation. The result shows the list of tenure forms based on its ranking. The most optimum tenure form is HP, followed by HGB, SKT, HK, and the NB system. The rest from the middle ranking to the least optimum are SWK, IL/IP, ST, SPI, SWBT system, and the least one is GR. HP is the most optimum tenure because, from the heuristic extensive and detailed evaluation of the tenure form versus the secure situation (Appendix 4), it shows the highest level of performance/applicability expression for most of the criteria and subcriteria of the tenure situation; for example, in the aspects of security, convenience of use, and recognition, it marks most as very good and just a few as good performance in our calculation. Grant, in contrast, shows very poor applicability in almost all of the subcriteria, so the calculation gives the lowest weight to this tenure form.

6.2.1.4 Seaward boundary

What is the extent of the seaward boundary within which tenure may be granted?

From our investigation, our study denotes that:

a. In Indonesia, the seaward boundary of coastal area management follows the sea jurisdiction of the province where the land is located, with the farthest distance being 12 nautical miles.
b. However, specific for housing tenure, it should applies:
    1) For local communities, tenure allocation is permitted within the intertidal zone. For practical purposes, the seaward boundary is following the maximum perpendicular distance of the shoreline to the outer limit of the zone.
    2) For indigenous law communities, the tenure can extend further seaward up to 2 nautical miles from the shoreline, allowing them to build housing within this broader range.
    3) If indigenous or local communities have established housing rules within the intertidal zone and 2 nautical miles, the seaward boundary follows their arrangement
    4) The housing arrangement has to follow the rules set by the Spatial Planning or another rule made by the local government within the intertidal zone and 2 nautical miles away.

6.2.1.5 Tenure forms that conform to the spatial plan

Which are the tenure forms that conform to spatial plan zones?

Table 57, 58, and 59 show the exposition of the answer. Below is the overview.

<u>Conformity to RTRW</u>

With RTRW, this study shows:

a. For cultivation/built-up areas
    1) All tenure forms can be applied to the zones accordingly. Table 57, as a modification from Table 24, shows conformed tenure forms in each zone.
    2) We found that HP (mostly for government bodies) and IL/IP-in the form of KKPR, can be assigned almost to all zones, from road to defense and security area, except for forest areas.
    3) As shown in Figure 27, with 12 matching zones, it can be concluded that IL/IP and HP has the highest applicability rate, followed by HGB (10 zones), SKT (10 zones). The lowest applicability rate belongs to SPI (no zone).
    4) Table 57 indicates that from total 15 zones, there are 13 zones where the appropriate tenure forms can be allocated into those zones. Mixed-use area and housing area become

two zones where most tenure forms can be applied to, indicating that these are zones where there is greater flexibility in the type of land tenure one can hold or acquire.

b. For protected areas
   1) Only HP, SKT, HK, SPI and IL/IP can be applied in the protected areas.
   2) IL/IP is the most applicable tenure form for protected areas.
   3) As presented in Table 58, from 10 total zones, 5 zones are relevant and the other 5 are not relevant. Although only with 4 tenure forms, for protected areas, cultural heritage zones still become the zone where most of tenure forms can be applied.

Table 57. Tenure form conformity with RTRW cultivation/built-up area zones

Allotment zones/Land use plan		**Conformed tenure forms**	**No. of conformed tenure forms**
Kawasan Budidaya (Built-up/cultivation areas)			
1. Road		HP, IL/IP	2
2. Production forest areas	Permanent production forest areas	None	0
	Convertible Production Forest Areas	None	0
3. Agriculture areas	Horticulture areas	SKT, ST, SWBT, GR	4
4. Tourism areas		HP, HGB, SKT, SWK, IL/IP	5
5. Industrial areas		HP, HGB, SKT, SWK, IL/IP	5
6. Residential areas	Housing areas	HP, HGB, SKT, HK, NB, ST, SWK, IL/IP, SWBT, GR	10
	Public facilities and social facilities areas	HP, HGB, SKT, HK, SWK, IL/IP	6
	Non-green open space areas (plazas, paved public areas)	HP, HGB, SKT, IL/IP	4
	Urban infrastructure areas	HP, HGB, SKT, IL/IP	4
7. Mixed-use areas		HP, HGB, SKT, HK, NB, SWK, IL/IP, ST, SWBT, GR	10
8. Commercial and services areas		HP, HGB, SKT, SWK, IL/IP	5
9. Office areas		HP, HGB, SKT, IL/IP	4
10. Transportation areas		HP, HGB, IL/IP	3
11. Defense and security areas		HP, IL/IP	2

Table 58. Tenure form conformity with RTRW protected area zones

Allotment zones/land use plan		Conformed tenure forms	No. of conformed tenure forms
Kawasan Lindung (Protected areas)			
1. Water bodies	Water bodies	IL/IP, SPI	2
2. Protective areas for the areas beneath/below	Protected forest areas	None	0
3. Local protection areas	Local protection areas	HP, IL/IP	2
4. Green open space	Urban jungle	HP, SKT, IL/IP	3
	City park	HP, IL/IP	2
	Cemetery/burial ground	Not applied	0
	Green belt	None	0
5. Conservation areas	Nature sanctuary areas	None	0
6. Cultural heritage areas	Cultural heritage areas	HP, SKT, HK, IL/IP	4
7. Mangrove ecosystem areas		None	0

Conformity with RZWP3K

Which are the tenure forms that conform to the zones of marine spatial plans?

a. For general purpose areas
   1) All tenure forms can be applied accordingly in General purpose areas. Table 59 shows the conformity summary.
   2) As shown in Figure 28, with 29 matching zones, IL/IP is the most applicable tenure form, indicating its broad applicability across various zones, followed by HP (fitted to 16 zones), and HGB (13 zones). The least applicable forms are NB, ST, and SWBT (each in 1 zone).
   3) The study finds that Housing zones, with nine assignable tenure forms, offers the greatest capacity for tenure allocation among all zones. Conversely, Forest, Heritage sites, Shipping lines, and Biota habitat are categorized as zones where no tenure forms are permitted.

b. For conservation areas
   1) All tenure forms are not eligible in every Core zones of Conservaton areas, only applicable in Limited use zones and Other zones of Conservation zones.
   2) IL/IP becomes the most compliant forms, can be assigned to 7 zones in Conservaton areas..
   3) In Beach corridor zone, HP, HK, and IL/IP are applicable.

c. For Specific National Strategic Areas
   1) Only HP and IL/IP that can be applied to any relevant activities for Military installation and Boundary zone and outermost islands.

d. For Sea channel
   1) Only IL/IP is relevant for Submarine pipes/cables activities.

Table 59. Tenure form conformity with RZWP3K zones

Allotment zones/Land use plan		Conformed tenure forms	No. of conformed tenure forms
Kawasan Pemanfaatan Umum (Area for General Usage)			
1. Tourism	Seascape nature tourism	IL/IP	1
	Beach	HP, SKT, HK, IL/IP	4
	Underwater tourism	IL/IP	1
	Historical and cultural tourism	HP, HGB, SKT, HK, IL/IP	5
	Water sport zone	IL/IP	1
2. Housings	House	HP, HGB, SKT, HK, NB, SWK, IL/IP, ST, SWBT, GR	10
3. Service and commercial		HP, HGB, SKT, SWK, IL/IP	5
4. Harbours	Port Working Area (DLKr) and Port Surrounding Area (DLKp)	HP, HGB, IL/IP	3
	Fishing ports	HP, HGB, IL/IP	3
5. Salt production		SKT, IL/IP	2
6. Forest	Mangrove		0
7. Mining	Mineral (bauxite)	HGB, IL/IP	2
	Sea sand	HGB, IL/IP	2
	Oil and gas	HGB, IL/IP	2
	Geothermal	HGB, IL/IP	2
8. Fisheries (fishing)	Pelagic	IL/IP	1
	Demersal	IL/IP	1
9. Fisheries (breeding)	Marine breeding (Karamba/Floating net cages)	IL/IP, SPI, GR	3
	Brackish water	IL/IP, SPI, GR	3
10. Industry	Fish processing (factory)	HP, HGB, IL/IP	3
	Maritime manufacture	HP, HGB	2
	Biopharmakology	HP, IL/IP	2
	Biotechnology	HP, IL/IP	2
11. Public facilities	Educational facilities	HP	1
	Religious facilities	HP, HGB, SKT, SWK	4
	Public buildings (Sports)	HP	1
	Waterfront park	HP	1
	Gas station	HP, HGB	2
12. Energy		IL/IP	1
13. Others (in line with the bio-geo-physical characteristics)	Anchor zone	HP	1
Kawasan konservasi (Conservation Areas)			
1. KKP3K	Core zones		0
	Limited use zones	IL/IP	1
	Other zones	IL/IP	1
2. KKM	Core zones		0
	Limited use zones	IL/IP	1
	Other zones	IL/IP	1

Table 59 (continued)

3. KKP	Core zones		0
	Usage zones	IL/IP	1
	Other zones	IL/IP	1
4. Sempadan pantai (beach corridor)		HP, HK, IL/IP	3
Kawasan Strategis Nasional Tertentu (Specific National Strategic Areas)			
1. Military installation		HP, IL/IP	2
2. Boundary zone and outermost islands		HP, IL/IP	2
3. Heritage sites			0
4. Endemic biota habitat			0
Alur Laut (Sea Channel)			
1. Shipping lanes			0
2. Submarine pipes/cables		IL/IP	1
3. Migration route of marine biota			0

Conclusion

The results reveal that IL/IP (17 zones) and HP (16 zones) emerge as the most compliant tenure forms with the RTRW. Similarly, these same forms demonstrate the highest conformity to the RZWP3K, with IL/IP matching 34 zones and HP matching 19. For the RTRW, SKT and HGB rank as the third and fourth most compliant tenure forms, aligning with 12 and 10 zones, respectively. In the RZWP3K, HGB takes third place with 13 zones, while SKT and SPI share the fourth position, both matching 6 zones. Figure 27 and 28 summarize the applicabilty rate of every tenure form. IL/IP, in the form of KKPR, shows high applicability from a spatial allocation perspective. This is most likely due to its role as a basic permit for formal rights and its broad coverage of activities given by the zoning regulations in the spatial plan documents.

6.2.1.6 Tenure forms that conform to the physical settings

Which are the tenure forms that conform to physical settings?

This study developed the concepts of physical settings by identifying the actual situations found in the study area that are affected by building appearances, housing stands (stilts or floats), connection to the mainland, inundation, and permanence. The result found nine physical settings of the aquatic land parcel where the tenure forms can be applied:

Aquatic land with building:

Setting 1 : Stilt, connected to the mainland, fully inundated, permanent building
Setting 2 : Stilt, connected to the mainland, fully inundated, non-permanent building
Setting 3 : Stilt, connected to the mainland, temporarily submerged, permanent building
Setting 4 : Stilt, connected to the mainland, temporarily submerged, non-permanent building
Setting 5 : Stilt, water-locked, temporarily submerged, permanent building
Setting 6 : Stilt, water-locked, temporarily submerged, non-permanent building
Setting 7 : Floating, water-locked, fully inundated, non-permanent building

Aquatic land without building:

Setting 8 : Fully inundated
Setting 9 : Temporarily submerged

Table 60, a modification from Table 26, presents the answer to the question. Setting 3 and 4 becomes the settings that most tenure forms can be applied (9 tenure forms). As a contrast, Setting 7 only has IL/IP as the applicable tenure form. To all settings, IL/IP becomes the most applicable tenure form, as it can be assigned to all settings, followed by SKT, NB, SWK, and SWBT. These forms are in the form of non-title-based, which gives them more flexibility concerning the formal restrictions. This study reveals that for water-locked, inundated, floating conditions, no tenure forms from BAL regime can be applied, as the regulations say so. Therefore, only tenure forms from other sources are applicable for Setting 5 to 9.

Table 60. Tenure forms conformity with physical settings

No	Setting	Conformed tenure forms	No. of conformed tenure forms
1	1	HP, HGB, SKT, HK, NB, SWK, IL/IP, SWBT	8
2	2	HP, SKT, HK, NB, SWK, IL/IP, SWBT	7
3	3	HP, HGB, SKT, HK, NB, SWK, IL/IP, SWBT, GR	9
4	4	HP, SKT, HK, NB, SWK, IL/IP, ST, SWBT, GR	9
5	5	SKT, NB, SWK, SWBT, IL/IP	5
6	6	SKT, NB, SWK, SWBT, IL/IP	5
7	7	IL/IP	1
8	8	IL/IP, SPI	2
9	9	SKT, IL/IP, SPI, GR	4

6.2.1.7 Rights, restrictions, and responsibilities linked to aquatic parcel land

What are the information of rights, restrictions, and responsibilities should be linked to aquatic land parcels?

To answer this question, our investigation, detailed in Chapter 3, focused on formal tenure forms from land-based regimes. The findings are presented in the following table.

According to the results as outlined in Table 61, the information on the rights, restrictions, and responsibilities of HP, HGB, and HK is largely consistent. The differences lie in the aspect of the convenience to transfer (i.e., prohibited for HK holders) and in the aspect of permitted use for commercial service (i.e., HGB is the only tenure type for commercial uses).

Table 61. Rights, Restrictions, and Responsibilities

Type of rights	Rights	Restrictions	Responsibilites
HP, HGB, HK	1. Occupy 2. Use the surface 3. Use the air space 4. Utilize the resources (mineral, water) 5. Sell (except HK) 6. Transfer (except HK) 7. Lease 8. Mortgage (except HK) 9. Grant (except HK) 10. Inherit (except HK) 11. Divide (*pemecahan*), split (*pemisahan*), merge (*penggabungan*)	1. Only allowed in the area which previously stipulated (*Penetapan Lokasi/*Location Determination) 2. Only allowed to built-up parcels and within the area following housing zone 3. Abandon 4. Blocking access/waterways 5. Damaging natural resources and environmental sustainability 6. Specific restrictions (intensity of space utilization) or building codes: - GSB (*Garis Sempadan Bangunan*)/Building boundary line - KLB (*koefisien lantai* bangunan/Building floor coefficient) - KDB (*Koefisian Dasar* Bangunan/Building Base coefficient) - KDH (Koefisian *Dasar Hijau*/Green Base Coefficiant) - KTB (*koefisien tapak bangunan*/building site coefficient) - KWT (*Koefisien wilayah* terbangun/Built-up area coefficient) - Kepadatan *bangunan*/Building density 7. Zoning regulation (ITBX Table) 8. Minimum parcel size 9. Sell are not allowed to legal body or outsider subjects 10. Rights cannot be convert to HM 11. Occupy for at least 20 consecutive years or more by the owners or their ancestors 12. Reclamations needs permit from the authoritative bodies	1. Releasing land if it is used for public purposes 2. Maintain surrounding infrastructure 3. Protect the environment 4. Extend or renew rights 5. Rights in small islands must consider public rights 6. Hand over the land after the rights to the land are erased 7. Develop buildings only for housing, religious facilities, public and social facilities (HK, HP), and for housing and commercial buildings (HGB) 8. Provide facilities and infrastructure for preventing and controlling land fires 9. Have received KKPR document only for HP and HGB 10. Using environmentally friendly building materials 11. Carry out development on the land in accordance with the purpose and requirements as stipulated in the decision to grant the rights no later than 2 (two) years from the date of stipulation 12. Technical: ▪ Register the SK Penetapan ▪ Pay BPHTP and Land Taxes (PBB) only for HP and HGB 13. Maintain boundary monuments/markings (if applicable)

To summarize, as shown in the table, the findings of this study indicate that in aquatic land parcels, there are eleven entitlements information about occupancy, utilization, transferability, and shape adjustment should be embbeded. Twelve specific restrictions, concerning land use, environmental protection, development intensity, zoning regulations, parcel size, and limitations on conversion, are identified as crucial information. In terms of responsibilities, there are thirteen information for rights holders to adhere to, spanning social (e.g., releasing land for public use, boundary maintenance), environmental (e.g., resource protection, fire prevention, sustainable construction), and administrative (e.g., obtaining necessary approvals, tax compliance) domains.

6.2.2 Findings from Objective 2 on cadastral survey system

This study has the 2nd aim:
To assess the application of Unmanned Aerial Vehicles (UAVs) for aquatic land tenure boundary acquisition in the coastline settlements

6.2.2.1 Form of aquatic parcel boundaries

What are the appropriate boundaries of aquatic land parcels under Indonesian cadastral system?

For aquatic land with buildings, all formal tenure forms coming from land-based regime (i.e., BAL and its derivative regulations) are having building footprints as the boundaries. The building footprint, representing the area occupied by a structure, can be derived by projecting its rooftop boundaries onto the water surface or tracing its outermost structural elements to define a perimeter. On the other hand, for tenure forms that come from non-BAL parties, the boundaries take the form of building footprints, fences, pillars, or imaginary-based boundaries (shown in a paper, without monumentation). Since the tenure system under BAL does not apply to vacant aquatic lands, these lands are governed solely by tenures from other regimes. The boundary of them, would be physical objects (fences, pilars) that are monumented (in case in intertidal areas) or imaginary-based/paper or floating buoy (in case in fully inundated areas/outside the intertidal areas). As conclusion, this study denotes that the boundaries of aquatic land parcels are not homogeneous. Formal stipulations, for example, determine the boundaries of tenure from statutory systems.

6.2.2.2 Optimum number of GCPs

What is the minimum number of GCPs required to achieve stable accuracy?

Addressing this questions, this study reveals that specifically for this study, minimum 6 GCPs are required to achieve stable accuracy. Our experiment shows that by using only 4 GCPs, the RMSE is still in the value of 0,3499. Increasing the number of GCPs to 5 points can add the accuracy by decreasing the RMSE (in m) to 0,3330; while using 6, 7, and 8 points, the RMSE will be 0,3034, 0,3333, and 0,3029 respectively. The largest gap occurs from using 5 GCPs to 6 GCPs, as the decrease of RMSE is 0,0296 m (2,96 cm). After the use of 6 GCPs, the experiment indicates that there is no significant effect on reducing RMSE of the orthophotos. There was only a reduction of error by 0,0001 m (0,01 cm) from 6 GCPs to 7 GCPs, and by 0,0004 m (0,04 cm) from 6 GCPs to 7 GCPs. In other words, if we consider time and affordability, 6 GCPs are the optimal number of required GCPs. Adding more GCPs will only provide a reduction in error in millimeters.

It is important to note that this study's conclusion—that six GCPs are the minimum number required to achieve stable accuracy—is a context-specific for this's study area. In general, the proper minimum GCPs depend on the topography, the size and shape of the area of interest (AOI), as well as the configuration of the GCPs and ICPs network.

6.2.2.3 Spatial accuracy

Do the produced orthophotos achieve the spatial accuracy required for cadastral base map?

This study investigates the accuracy using four standards, and the results shows that the produced orthophotos achieve the required spatial accuracy. Table 62 summarizes the results.

Table 62. Result of accuracy analysis

Standard source	Regulation	Measure used	Produced orthophoto	Requirement	Conclusion
Indonesian Geospatial Agency (BIG)	Head of BIG Regulation No. 15 of 2014	CE90	CE90 = 0,46 m	Map scale of 1:1.000 for Class 3, where 90% of errors/CE90 ≤ 0,5 m for horizontal positions. Map scale of 1:2.500 for Class 1, where 90% of errors/CE90 ≤ 0,5 m for horizontal positions.	The orthophoto accuracy meets BIG's standards for both 1:1.000 (class 3) and 1:2.500 map scale (class 1)
Ministry of ATR/BPN	Agrarian State Minister Regulation No. 3 of 1997 (PMNA No. 3/1997)	RMSE	RMSE = 0,3029 m Orthophoto scale = RMSE/0,3 mm = 1:1.009 ~ 1:1.000	1:1.000 scale for urban areas and 1:2.500 scale for agricultural/suburban areas.	The orthophoto accuracy meets ATR/BPN's requirements for urban (1:1.000) and suburban/agricultural (1:2.500) mapping scales.
IAAO (International Association of Assessing Officers)	IAAO Guidelines, 2016	Mapping scales	Orthophoto scale = 1:1.009 ~ 1:1.000	Commonly used mapping scales are 1:1.200 for urban zones, 1:2.400 for suburb areas, and 1:4.800 or 1:9.600 for rural areas	The orthophoto scale aligns with IAAO's recommended scales for urban and suburban mapping areas.
Ministry of ATR/BPN	Guidelines No. 2 of 2017 about Working map creation using drones	CE90	CE90 = 0,46 m	Tolerance limit: "0,5 mm × map scale" for land sector in urban area. Thus, for 1:1.000, maximum error/CE90 = 0,5 m.	The orthophoto meets the accuracy standards for land mapping in residential/urban areas.

6.2.2.4 Duration and cost of UAV survey

Is the UAV operability fit-for-purpose in terms of duration and cost?

Duration

For fit-for-purpose land administration, which emphasizes affordability and the rapid achievement of secure land rights, conventional terrestrial and GPS surveys prove too slow. This study indicates their pace is ill-suited to the fit-for-purpose principle of prioritizing speed for broad coverage, especially when large areas require quick surveys.

The UAV-based image approach exhibits significantly greater time efficiency compared to the traditional terrestrial survey method. While terrestrial surveys typically take around 30 days to cover areas over 40 hectares with an 8-hour workday constraint, this study shows that a UAV-based approach mapped 3.956 parcels across 400 hectares in just 14 days. This indicates that, for an area 10 times larger, the UAV method is twice as fast. Furthermore, when considering the number of parcels, if a GPS survey team can produce 24 parcels per day and typically deploys three teams per day, it would take 55 days to complete 3.956 parcels. Therefore, the UAV survey method is approximately 4 times faster than the GPS survey method. The UAV-based approach, which completed the survey of 3.956 parcels over approximately 400 hectares in just 14 days, demonstrates significantly greater time efficiency. This method covered an area 10 times larger in half the time compared to terrestrial methods, which is highly consistent with fit-for-purpose principles.

This study confirms the suitability of the UAV-based survey method in terms of duration. By significantly reducing the time required to survey large areas and complete a high number of parcels, the UAV approach enables rapid, broad-scale implementation of land administration projects. Such an approach is crucial for achieving timely and equitable land rights in contexts where speed and coverage are paramount. The efficiency gains of the UAV method make it a strong candidate for fit-for-purpose land administration strategies, especially when compared to the slower terrestrial and GPS survey methods.

Cost

In the context of a terrestrial survey, the calculation reveals that the cost per parcel is Rp129.300. Given that there are 3.956 parcels within the Area of Interest (AOI), the total cost for the cadastral measurement of all parcels amounts to Rp511.510.800. In contrast, the total fee for conducting a survey and producing all parcels' boundaries using an Unmanned Aerial Vehicle (UAV) is Rp36.740.000. This means that using a UAV survey, the cost per parcel is Rp9.287, making it 15 times cheaper than the cost of a cadastral survey conducted using terrestrial methods. The comparison between the terrestrial and UAV survey methods highlights a significant difference in costs. The terrestrial survey incurs a much higher total cost for cadastral measurements, whereas the UAV survey offers a more economical alternative. This suggests that UAV surveys could be a more cost-effective solution for large-scale cadastral assessment.

The concept of "fit-for-purpose" land administration emphasizes solutions that are simple, cost-effective, and scalable to quickly cover large areas with adequate accuracy, rather than relying on high-cost, precision methods suited to developed nations. The terrestrial survey, costing Rp129.300 per parcel and Rp511.510.800 for the entire AOI, reflects a traditional approach that prioritizes high accuracy. However, these costs are relatively high, which may not align with the fit-for-purpose approach, especially for large-scale implementations where cost and speed are critical. As a contrast, the UAV survey, with a total cost of Rp36.740.000 and a per-parcel cost of Rp9.287, is significantly lower. This approach is more in line with the fit-for-purpose model, as it provides a balance between cost, speed, and adequate accuracy, making it more accessible for large-scale land administration projects. The UAV method offers a much more affordable and scalable solution, making it well-suited for rapidly achieving broad coverage in cadastral assessment, particularly in contexts where resources are limited and the emphasis is on achieving adequate rather than high precision. The terrestrial survey, while accurate, may be less aligned with the fit-for-purpose approach due to its higher costs and longer implementation time.

Finally, from both findings, It can be concluded that the UAV system is fit-for-purpose in terms of durability and cost.

6.2.2.5 Boundary quality

How close is the general boundary from semi-automated feature extractions to the reference boundary in terms of completeness, correctness, and quality?

These are this study's findings and conclusions while answering the above question.

Building identification using completeness, correctness, and quality category

1. Semi-automatic techniques cannot be applied to areas with irregular (both in shape and size), very dense, huddled buildings, as the boundaries of the buildings cannot be visually distinguished.
2. The quality results from the OBIA and Mapflow.AI analyses, as assessed across two different sites, reveal significant differences in performance. (note: Site 1 is more homogeneous in terms of the rooftop color of the building, the shape of the building, and the distance between buildings, while Site 2 is more heterogeneous in color, there are regular parts of distance, size, and there are housing clusters whose patterns are not uniform at all, and some are water-locked buildings):
    a. The OBIA analysis for Site 1 demonstrates high-quality results, with a completeness, correctness, and quality of 92,41%, 89,33%, and 83,22% respectively, for object-based evaluation, while for area-based evaluation the corresponding values are 94,86%, 93%, and 88,78%. This suggests that OBIA is effective in accurately identifying the area as buildings on this site. In contrast, Mapflow.AI's analysis using object-based evaluation and area-based evaluation for Site 1 shows a significantly lower quality result. With a completeness, correctness, and quality of only 49,63%, 61,22%, and 37,76% respectively, for object-based evaluation and of 60%, 85,88%, and 54,56%, it reflects the limitations of Mapflow.AI in this context.
    b. The OBIA analysis for Site 2 also performs well, achieving a completeness of 84,22%, a correctness of 89,66%, and a quality of 76,76% in object-based evaluation. For area-based evaluation, the values are 89,67% for completeness, 92,57% for correctness, and 83,56% for quality. These results suggest that OBIA provides reliable outcomes for this site. On the other hand, for Site 2, the performance of Mapflow.AI shows slight improvement over its performance in Site 1 in object-based evaluation, but it still falls short compared to OBIA. Mapflow.AI's completeness is 47,77%, and its correctness is 76,20%, indicating a moderate ability to accurately identify buildings. However, the branch factor (0,31) and miss factor (1,09) highlight ongoing challenges with false positives and false negatives. The overall quality score of 41,57%. In area-based evaluation, Mapflow.AI achieves scores of 61,29% for completeness, 83,43% for correctness, and 54,64% for quality. The results suggest that while Mapflow.AI has some utility, it is less reliable than OBIA for this site.
    c. OBIA consistently outperforms Mapflow.AI in both sites, with higher completeness, correctness, and quality scores. This suggests that OBIA is more accurate and reliable for building identification in the analyzed areas. Mapflow.AI struggles with a higher incidence of false positives and false negatives, leading to lower quality scores overall. Its performance is significantly lower, particularly in terms of completeness, indicating it may miss a considerable number of buildings in the analysis.

Building identification result using Matched, Over-bordered, Under-bordered, and Failed category

However, although the result above indicates an adequate level of quality, actually the analysis was conducted only based on the number of objects and their coverage areas rather than on a one-to-one of the object correspondence. Therefore, we performed a more detailed visual analysis of the OBIA result by means of GIS to achieve a one-to-one match between the buildings in the reference dataset and studied dataset, aiming to have a clearer understanding of the result and select the buildings for the subsequent boundary validation process.

1. In Site 1, a total of 134 buildings were assessed, with varying levels of accuracy in the extraction process. Of these, 43 buildings (32,09%) were successfully matched with the reference dataset, meaning their boundaries were correctly identified. However, 37 buildings (27,61%) failed to be properly extracted, either going undetected or with less than 50% of their boundaries accurately identified. A significant portion, 54 buildings (40,30%), were under-bordered, indicating that multiple buildings were incorrectly grouped as a single unit. Notably, there were no cases of over-bordered buildings, where a single building is mistakenly separated into multiple parts.
2. In Site 2, a total of 220 buildings were assessed, with varying outcomes in the extraction process. Of these, 99 buildings (45%) were successfully matched with the reference dataset, indicating that their boundaries were accurately identified. However, 85 buildings (38,64%) were not properly extracted, either going undetected or having less than 50% of their boundaries correctly identified. Additionally, 17 buildings (7,73%) were under-bordered, where multiple buildings were incorrectly grouped as one, and 19 buildings (8,64%) were over-bordered, where a single building was mistakenly separated into multiple parts.
3. Upon closer visual examination, distinct patterns emerge within each categorization of building extraction. In the Matched category, buildings that are clearly separated from surrounding structures by bodies of water or roads tend to be successfully identified. This pattern is evident in both Site 1 and Site 2, with an additional observation in Site 2 that buildings located in water are more likely to be correctly matched. In the Under Bordered category, buildings that are too close to their neighbors or have unclear boundaries are often grouped together as one, a trend seen in both sites, particularly in irregular settlement clusters in Site 2. The Over Bordered category includes buildings where the boundaries between adjacent structures are blurred, leading to over-segmentation in both sites. Finally, the Failed category reflects detection failures without any specific identifiable pattern, similar to the challenges seen in the Under Bordered and Over Bordered categories.
4. The performance of the segmentation process was more favorable at Site 2, likely due to better visual quality and more distinct building shapes, despite a higher rate of over-bordering and failures. Site 1, on the other hand, struggled with under-bordering, leading to a lower accuracy in building extraction.
5. Therefore, although the example-based semi-automatic segmentation method in this research overall provided less satisfactory results (i.e., matched category for both sites are having less than 50% of the buildings), it can still be stated that there are certain types of buildings and residential clusters that are potentially suitable for application. These include clusters that are orderly and have clear and distinct boundaries between buildings (either separated by roads or bodies of water). In such cases, water-locked buildings are a type of building where boundaries can be effectively delineated using the semi-automatic segmentation method.

Boundary validation

Using the **Macthed** buildings from OBIA analysis, the result comparison between the boundary from OBIA Analysis and Mapflow.AI for Sites 1 and 2 reveals that in Site 1, OBIA outperforms Mapflow.AI with higher completeness (97,73% vs. 79,97%), correctness (90,40% vs. 86,72%), and quality (93,25% vs. 82,60%). Similarly, in Site 2, OBIA also leads, with completeness at 89,22% compared to 67,90% for Mapflow.AI, correctness at 86,01% vs. 74,45%, and quality at 87,59% vs. 70,98%. It should be noted that, although the validity scores are high, it is only applied to matched category buildings and only by using a big 100 cm tolerance of buffer zone in boundary comparison analysis.

Conclusion

The study demonstrates that semi-automatic segmentation techniques, particularly OBIA, generally outperform Mapflow.AI in identifying and extracting building boundaries, especially in areas with clear separations. OBIA consistently achieved higher scores in completeness, correctness, and quality across both sites, indicating its greater reliability and accuracy. However, both methods struggled in areas with dense, irregularly shaped buildings, where boundaries were difficult to distinguish visually. The study also highlighted that OBIA's performance is better in more distinct and water-locked building clusters, though less satisfactory overall, as matched buildings were less than 50% of the total for both sites. Despite the challenges, OBIA shows potential in specific contexts, especially where buildings are clearly separated by roads or bodies of water. In contrast, Mapflow.AI, while slightly improved in some areas, still lags behind OBIA in reliability and accuracy, particularly in more complex urban settings.

Boundary validation confirmed OBIA's superior performance in Matched categories. The OBIA boundaries are relatively close to the reference boundaries in terms of completeness, correctness, and quality. This suggests that OBIA is capable of producing boundaries that closely match the reference, particularly in areas with distinct building separations. However, in more complex or irregular areas, the performance may vary, but OBIA still provides closer approximations than Mapflow.AI.

6.2.3 Findings from Objective 3 on land valuation

This chapter presents the results corresponding to the study's third objective *"to develop and assess aquatic land valuation in the coastline settlements",* which is centered on the development and assessment of land valuation within aquatic land settlements. The findings elucidate the complexity inherent in aquatic land valuation, offering insights into the economic, environmental, and social parameters that critically inform and shape valuation practices in these unique settings.

6.2.3.1 Specific affecting factors of land value

What are the relevant affecting factor of aquatic land value?

Seventeen factors are relevant to the valuation. These, as detailed in Table 44 of Chapter 5, include economic factors (date of property transfer, property price, and interest rates); tenure status (law, government, and politics); physical factors (property use, depth, building age, size, quality, frontage, and road functional class); an environmental factor (sea view); and locational factors (distance to the central fish market, land, nearest port, roads, and waterways).

Among these factors, property price, interest rates, date of sale/transaction, property use, tenure status, building age, building quality, and property size were employed to construct the adjusted land value as the dependent variable. The remaining nine factors—depth, distance to the central fish market, distance to land, distance to the nearest port, frontage, and sea view, road functional class, access to road, and access to waterway—were utilized as independent variables.

6.2.3.2 Principles of valuation

How the land value is modeled (what are the principles of land valuation for aquatic land parcel in the study area?)

This thesis, on the conducted valuation, demonstrates the following principles:

1. The valuation is a hedonic mass-valuation established on a parcel-based approach. The value is calculated on an individual parcel basis that makes every land parcel can be evaluated according to its unique characteristics while maintaining consistency across the broader region.

2. Preliminary zones are created from adjusted Thiessen polygon and not delineated based on existing land uses. Within these zones, a comparison-score technique is is deployed to calculate the value of every parcel in the zones.
3. Final value zones are formed by aggregating parcels that share equivalent scores. Each zone defines a separate 'value zone,' where its parameters are determined by the boundaries of the associated parcels.
4. Consequently, the boundaries of the zones align with the boundaries of parcels within the same class. The boundaries of the value zones are designed to match the boundaries of land parcels within the same classification. This alignment ensures consistency and accuracy in the valuation process, as each zone precisely corresponds to the actual parcels on the ground.
5. A fundamental dataset required in the early stage is a comprehensive land parcel map. This map serves as the basis for all subsequent analysis, ensuring that all land parcels are accounted for and properly classified
6. Sample selection is a critical element and must meet the minimum number required by statistical tests. Although our approach only need a sample as minimum as one per zone, in total, the number of samples must meet the minimum statistical requirements. Achieving the minimum number is essential for the model to remain representative and produce accurate estimates across the entire area.
7. This estimation in this study is a context-sensitive estimation. The factors influencing value are selected and modeled based on the characteristics of the area. This approach allows the valuation model to account for local variations, providing more accurate and context-sensitive results.
8. These influencing factors encompass various aspects, including economic, legal, governmental, political, physical, environmental, and social dimensions. The factors from sea and land environment need to be used together.
9. Spatial factors are primarily generated from remote sensing data (e.g., UAV orthophotos) using GIS techniques.
10. A GIS environment is important to manage spatial and attribute data of the parcel, and then present the distribution of values. This spatial representation helps stakeholders understand geographic variations of value, facilitating better decision-making.
11. Non-spatial data are obtained from field surveys and secondary sources. Non-spatial data, which include information on economic activities, legal regulations, and social conditions, are collected through field surveys and secondary sources. This data complements the spatial analysis, providing a complete picture of the factors influencing land value.
12. A rationality test is essential. Both the F-test and T-test contribute to the refinement of the model by identifying which variables are statistically significant. This process allows for the exclusion of irrelevant or redundant variables, leading to a more accurate and reliable land valuation model. By confirming the statistical significance of the model and its variables, these tests can provide confidence that the model will perform well in various scenarios and geographic areas.

6.2.3.3 Value distribution

This part aims to give answer to the question:

How is the distribution of land value in the study area?

The calculation process identified eight distinct land value zones. The lowest value zone is Zone A, with values ranging from Rp45.000 to Rp165.000, while the highest value zone, Zone H, ranges from Rp1.251.000 to Rp1.700.000. The land value map, as shown in Figure 67, presents a range of estimated land values distributed across different areas, classified according to their value. The highest land values, ranging from Rp1.251.000 to Rp1.700.000, are concentrated in the western regions, particularly near the port and central fish market. This high-value class, marked in red, represents areas with excellent road access, higher road functional class, and proximity to significant economic centers.

Table 46 further highlights that this highest value class contains the fewest parcels (61 parcels) and the smallest total area (3.948 m² or 0,39 hectares), representing highly exclusive, premium land areas that are very limited in space but command the highest values.

The mid-range value zones, Zones D and E, which span from Rp400.000 to Rp550.000 and from Rp551.000 to Rp730.000 respectively, are depicted in yellow and orange and are spread across the central portions of the map. These areas benefit from decent road infrastructure and moderate proximity to key locations like the port and market. The largest area is found in one of these mid-range zones, Zone E, covering 79.860 m² or 7,9 hectares, which also contains the second-largest number of parcels.

Lower values, ranging from Rp45.000 to Rp550.000, are primarily located in the eastern parts of the map, depicted in green shades. This area includes the largest number of parcels (535 parcels) and the second-largest total area among all zones (74.224 m² or 7,4 hectares). These regions are characterized by limited road access, lower road functional class, and greater distance from major economic hubs, such as the port and market, leading to reduced values.

The distribution of value classes indicates that land value is heavily influenced by accessibility and proximity to key economic and infrastructural elements. Additionally, there is a clear inverse relationship between land value and both the number of parcels and total area: as land value increases, the number of parcels and total area tend to decrease.

6.2.3.4 Performance of the valuation

How good is the performance of the valuation?

Goodness of fit (F and t test, R value, and standar error of estimate)

The ANOVA results from the F-test indicate that the regression model has strong explanatory power. The model explains a significant portion of the variation in the dependent variable (ln_landvalue), as evidenced by the high sum of squares for the regression (1008,151) compared to the residual (352,103). The F-statistic of 766,390, which is derived from the ratio of the regression mean square to the residual mean square, further confirms the model's significance. The p-value of 0,000-well below the standard significance level of 0,05–reinforces the conclusion that the independent variables in the model collectively have a substantial and statistically significant effect on the dependent variable. This suggests that the chosen predictors are effective in explaining the variability in land value, validating the overall regression model's robustness. From the t-test result, it is revealed that access to roads, road functional class, proximity to key locations (such as the nearest port and central fish market), and physical characteristics (like depth and frontage) significantly influence land value in the study area. The significance of these factors underscores their importance in determining land valuation, while the lack of significance for access to water and sea view suggests these features do not contribute significantly to land value within the context of this model.

The model offers a comprehensive evaluation of the regression model's effectiveness. It reveals that the coefficient of determination (R^2) is 0,741, indicating that approximately 74% of the variability in the dependent variable is explained by the independent variables included in the model. The Adjusted R^2, closely mirroring the R^2 value, implies that the inclusion of additional independent variables does not significantly enhance the model's ability to account for variability in the data. The Adjusted R^2 value, which is almost identical to R^2, suggests that the addition of independent variables to the model does not result in a significant improvement in the model's ability to explain variability in the data. The Standard Error of the Estimate by 0,38231, represents the average estimate of prediction error in measuring the dependent variable. This indicates the degree of variability in the observed values of ln_landvalue that is not accounted for by the regression model. In summary, the model appears to be a robust model. The distance to market (di_markt) has the strongest influence on land value, followed by distance to land (di_land) and depth. The model demonstrates a strong explanatory power, capturing a substantial portion of the variance in ln_landvalue, although there may be some unexplained variability remaining.

Performance of UAVs for land valuation

Following the idea of spatial framework of FFP approach, the use of imagery is mainstreamed in land valuation process. This research effectively demonstrates the integration of UAV orthophotos and GIS. The orthophotos, processed through GIS, allow for the efficient extraction of spatial data, including depth, road functional class, sea views, distances to any points of interests (market, port, etc), access availability, and frontage. The ability to derive multiple data points from a single orthophoto highlights the versatility and cost-effectiveness of UAV technology, making it a valuable tool in large-scale land valuation without the need for exhaustive field surveys. The high accuracy of UAV imagery, along with the processing capabilities of GIS, makes the data reliable and suitable for detailed spatial analysis. It is also can be said that the use of GIS in this study is pivotal, facilitating a data-driven approach that enables a comprehensive and nuanced analysis of the spatial characteristics influencing land values. By deploying various GIS features such as interpolation, network analysis, and attribute scoring, the research achieves a precise quantification of land parcel characteristics, which are then used to create a detailed land value zone map. This map, with its clear visual representation of land values, serves as an essential tool for stakeholders, enabling informed decision-making in land management. In short, this study reveals that UAV system combined with GIS can perform satisfactory in supporting land acquisition process with regard to the provision of spatial-related data.

6.2.4 Overall conclusion

This study demonstrates that the proper strategy developed to address tenure insecurity in aquatic land settlements is multidimensional. The proposed tenure development configures a hybrid tenure arrangement, specifically in terms of its governance and implementation processes, adapted to the legal-spatial context. The cadastral survey system should be implemented by prioritizing the development and integration of semi-automatic feature detection as a cost-effective and rapid method for generating selective building footprint boundaries from UAV imagery as part of its operational methodology. The valuation framework adopts a context-specific, parcel-based hedonic mass appraisal approach. Despite several limitations, its assessment results and findings concludes that this strategy offers a promising service for delivering fit-for-purpose land attributes to assure legal recognition, spatial reliability, and value-based certainty.

6.3 RECOMMENDATIONS

From the insights derived from the discussion and conclusion sections, this thesis offers several key recommendations. The recommendations highlight practical development and future research.

6.3.1 Practical recommentations

6.3.1.1 Establish protocol to administer aquatic land parcel

Given the fact that arranging tenure for land in coastal areas is a composite actions involving numerous parties, aspects and steps, this thesis recommends the implementation of a protocol designed to optimize the arrangements, thereby ensuring secure tenure, avoiding confusion, and preventing wrongful actions. By establishing a protocol, the processes involved are carried out in a consistent, orderly, and reliable manner.

In this study, the protocol is conceptualized as a series of specific steps and actions necessary to achieve the desired outcome of arranging tenure for specific aquatic land parcels. The steps was development from the delivered findings of this study. The proposed protocol is illustrated in the following flowchart.

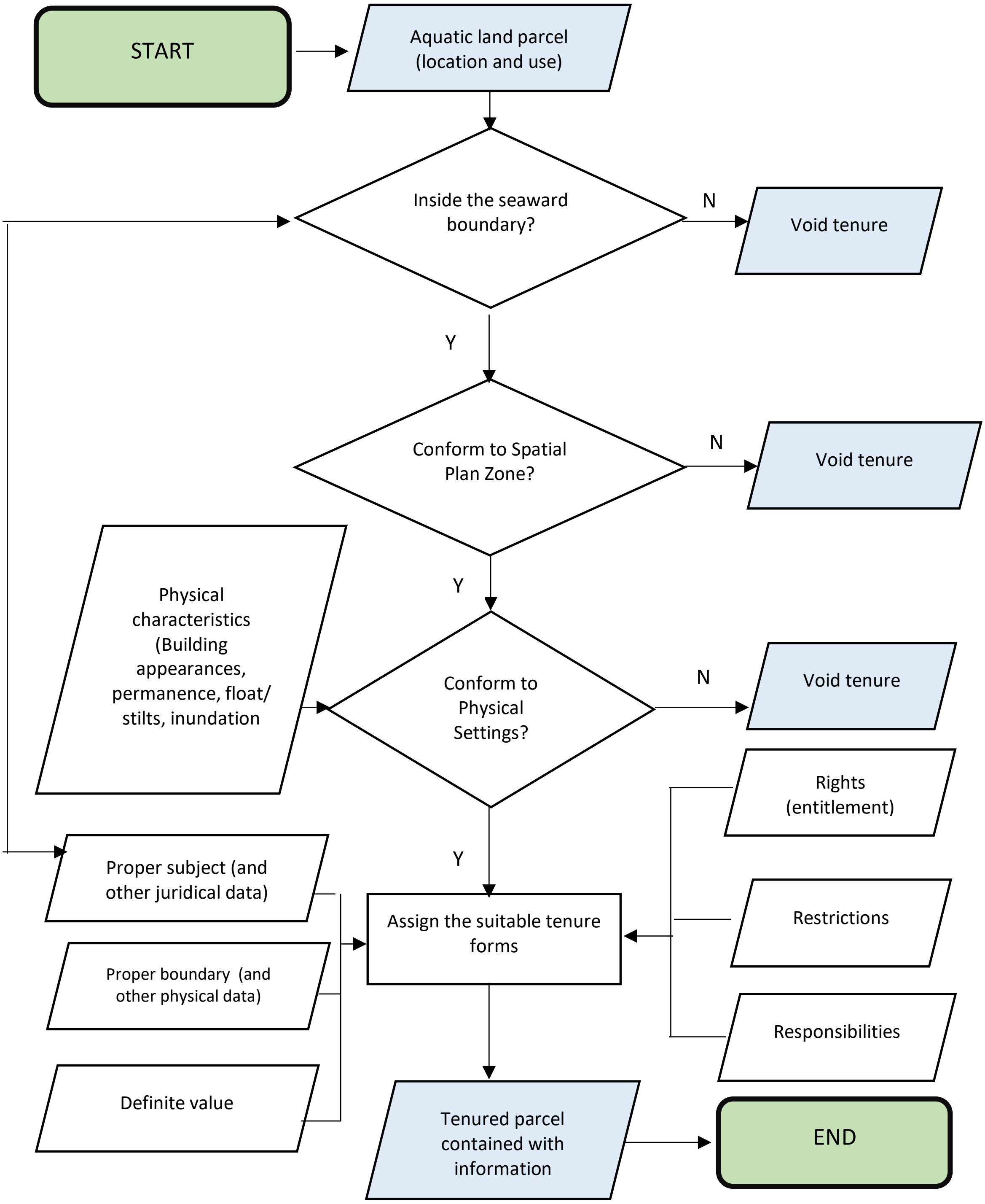


Figure 68. Protocol to arrange a tenure form into a piece of land in aquatic environment

The protocol as shown in Figure 68, can be explained as below:

1. When a piece of land in coastline settlements needs to be administered (and further be registered formally), a precise location should be available in the national coordinate system, as well as the information about existing and future use/allotment of the land.
2. Once the location is determined, it is important to check the position of the parcel by considering seaward boundary. The process also notices who the entities/persons/people that will be the subject of tenure. The check aims to make sure whether the parcel is located inside the seaward boundary or outside the boundary. If the parcel is within the seaward boundary, the process continues to the next step. If the parcel is not within the seaward boundary, the tenure is considered void, and the process stops.
3. The next decision point checks whether the parcel's use conforms to the Spatial Plan Zone. If the parcel conforms to the spatial plan, the process continues. If the parcel does not conform to the spatial plan, the tenure is considered void, and the process ends.
4. After that, the process evaluates whether the parcel meets the required physical settings from the combination of building appearance, permanence, foundation type (floating or on stilts), and inundation conditions. If the parcel complies, the process continues; if not, the tenure is void and the process ends.
5. Subsequently, the process will select and assign the appropriate tenure forms to the parcel. In this step, it is important to consider the necessity of transforming older forms of tenure, such as ST and Grant, which originated from past administrative processes, into more current forms to increase tenure acceptance in modern society. Prior to this assignment, it is imperative to identify the eligible subject in accordance with the chosen tenure type and to establish the appropriate boundaries based on the type of cadastral objects. For rights/title-based tenure, the boundary can be generated by a cadastral survey system (i.e., UAV-based survey). Following this, the tenure will be granted in accordance with the boundaries.
6. In conjunction with the process of granting tenure, it is essential to set specific details regarding the value, entitlements, restrictions, and responsibilities associated with the parcel.
7. The final result is the tenured parcel with embedded information.

Implementing a protocol for arranging tenure in coastal areas offers benefits by providing a structured approach to managing complex land use (both existing and future uses) and ownership issues. Such protocols is important to make that tenure arrangements are systematically aligned with property development and coastal zone management plans. This structured approach helps in minimizing conflicts over land use. Even more, by adhering to a standardized protocol, stakeholders (i.e., the owner and other interested parties) can achieve greater clarity over the parcel, which reduces the risk of disputes and environmental degradation.

Formal tenure issued by government authorities typically offering greater security and more legalized entitlements, but with more restrictions. On the other hand, with the consequences of smaller security, non-title format, for example permit format and informal tenure forms offer more flexibility (e.g., flexibility in location, less bureaucratic process, quicker and easier transactions) and less formal responsibilities.

If one wants to obtain high-security tenure in the form of title/rights under the Basic Agrarian Law (BAL), the following regulatory conditions must be met in the protocol:

Physical manifestation
The rights must be physically manifested through the presence of structures (e.g., buildings) and be supported by pillars or foundations embedded in the seabed. The rights also only be given within the building's footprint as its boundary. The land area outside the building or connected fence could still be possessed, used, and tenured by the holder, but without BAL-based formal title given by the

authority. Additionally, the construction must comply with local regulations, as evidenced by a Building Permit.

Availability of KKPR
The rights applied for must align with the land use directives/allotment outlined in the Regional Spatial Plan/ RZWP3K/ the Detailed Spatial Plan (if available later) evidenced by the KKPR document from the authorities. The document is a one of the formal documents required to register the parcels at the Land Office.

Located outside protected areas and inside the stipulated seaward boundary on the formal maps
The rights must not be situated within a protected area. This includes ensuring that the land parcel is not within a forest area, as verified by a statement from the Forestry Department. For specific land uses, such as industry and mining, an Environmental Impact Assessment (AMDAL) is required. Once the intertidal seaward boundary with relevant scales has been stipulated in formal maps, for example in the Coastal Environment Map (*Peta LPI*)/ Indonesian Rupabumi Map (*Peta RBI*), or Indonesian Marine Map (*Peta Laut Indonesia*) from Hydro-Oceanographic Center of the Indonesian Navy, as the sources of formal cartographic depiction of marine and coastal environment, the land title-based tenure assignation should comply to this boundary.

No interference with navigation and safety zones
The land rights must not disrupt public navigation routes, port access, or safety zones. A statement from the local Transportation Department (*Dinas Perhubungan*) is required to confirm that the settlement or building above water does not interfere with these areas.

It is also recommended to transform the descriptive protocol and its arrangements into a digital protocol by developing and implementing a web-based information system as a digital tool and platform for disseminating important information about land. This system can support a digital service ecosystem, which can strengthen tenure security by raising one's knowledge and awareness about rights, restrictions, and responsibilities when the person occupies land in coastal areas as a complex environment.

This system should integrate several key functionalities to streamline the tenure administration process.

1. First, it should include a geospatial component that allows for precise location determination of the coastal parcels within the national coordinate system, incorporating both existing and projected land use data. The system should facilitate the automated verification of parcel locations relative to the seaward boundary and guarantee compliance with Spatial Plan Zones.
2. Additionally, the web-based system should incorporate decision-support tools to evaluate whether parcels meet physical setting requirements, such as building characteristics and inundation conditions. By automating these checks, the system can reduce manual errors and expedite the decision-making process.
3. Furthermore, the system should support the selection and assignment of appropriate tenure forms while given the information about the subjects. Access to cadastral survey data and UAV-based survey results should also be facilitated.
4. It should also enable the integration of the parcel with detailed information on parcel value, obtained from land value estimation activities, and also information on the entitlements, restrictions, and responsibilities. The integration of rights, restrictions, and responsibilities (RRRs) into land rights should not only be implemented by adding a separate entry in the land registry database but also by manually including this information in key documents, such as certificates and contracts. In contracts, the RRRs information can be incorporated within the main body of the agreement, typically after the section detailing the terms and conditions of land use and before any general provisions or termination clauses. For certificates, this information should be integrated after the primary details of the land description (such as location, size, and boundaries) and before the legal declarations and signatures. The thesis also

suggests that this recommendation would need backup or clarification from further research focused specifically on this topic.

In the implementation of this web-based information system, when accessing the system, stakeholders can achieve greater transparency, improve accuracy in tenure assignments, and be facilitated more effectively in assessing tenure risks and making informed decisions. Future developments could include incorporating advanced data analytics and predictive modeling to further enhance the system's capabilities and adaptability to changing environmental and regulatory conditions.

6.3.1.2 Area-effective boundary determination

The process of generating parcel boundaries from building footprints using a semi-automatic approach suggests that this technique is most effective for buildings with regular shapes and clear distinctions between structures, including water-locked buildings. Consequently, it is essential to be selective when choosing the area of interest. Understanding which areas are suitable for boundary generation using semi-automatic techniques and which are not is crucial for ensuring efficiency and the reliability of results. For small areas, or regions characterized by densely packed buildings with minimal or unclear gaps between them, alternative methods, such as distometer measurements, may be more effective for boundary delineation.

6.3.1.3 Value for planning

Based on the findings related to the specific factors affecting aquatic land value, this study recommends prioritization of key economic and physical variables. Given the significance of factors such as access to road, road classification, distance to port, distance to market, distance to land, and depth, these variables should be prioritized in future valuation models, without throwing away the other variables. These variables have shown a strong correlation with land value and should be central to the assessment process.

Given that this thesis employs parcel-based mass valuation, where land parcel maps serve as the foundation for creating value zones, the availability of comprehensive parcel maps in the area of interest is essential. Similarly, transaction or offer records data functioning as samples is critical for establishing a basis for valuation calculations. Spatial technologies and tools, such as UAVs and GIS, have proven effective in supporting data production, value estimation, and visualization. This study recommends the regular and continuous use of these technologies to monitor and update data availability and land value maps, ensuring they reflect changes in infrastructure, geometry of the parcel, and land use. Regular updates will provide accurate insight for planning and decision-making.

Land value map is not only functioning as a basis for taxes and revenue but also is important for planning activities related to future land use development. For high-value zones, the development should be directed towards maintaining and optimizing road access and functional class to further attract premium developments and investments. For middle-value zones, these areas should be optimized for mixed-use developments or community-focused projects that leverage the decent infrastructure and proximity to economic centers. Providing good-quality infrastructure in these zones might potentially elevate their land values over time. In lower-value zones, the government should invest in improving road access and infrastructure, which provides better connectivity to major economic hubs.

6.3.2 Future research

Building on the investigations, limitations, and the findings, it is suggested that future studies may prioritize on the following aspects:

1. This thesis uses only AHP and Fuzzy TOPSIS for multicriteria analysis. Future research could explore other multicriteria analysis tools for comparison and incorporate sensitivity analysis to support the credibility of the decisions. Our findings from that multicriteria analysis (trade-off)

and conformity analysis show the heterogeneity mapping of the tenure forms for coastal areas. The coexistence of elements that constitute a hybrid tenure system within a national framework presents challenges, particularly regarding the integration of forms in the procedures (where one may precede others) and the presence of layered rights (where different tenure forms may exist over the same piece of land). This situation raises an urgent open question: *"What are the social, economic, and ecological impacts of tenure heterogeneity implementation on coastal land administration, and how can they be mitigated?"* This would help in designing future research on technology-driven policy innovation for inclusive governance when developing digital platforms that can assist involved land parties in making decisions during tenure arrangement processes.

2. This research uses the orthophoto from UAV surveys as a raster source for boundary detection. The findings from this study indicate the compromised orthophoto quality within densely populated study areas. This impacts the accuracy of semi-automatic edge detection algorithms in complex urban environments characterized by dense building clusters and irregular shapes. An open question for this: *"Whether this condition is really inevitable in some degree or if it can still be anticipated? How can the accuracy and reliability of semi-automatic edge detection be improved in such challenging conditions?"* Future research could investigate the incorporation of LiDAR, which provides highly detailed height information and other relevant strategies, into UAV survey systems in order to compare the quality of results and also the development of interactive tools that enable users (e.g., surveyors, local authorities) to manually adjust boundaries where automated methods fall short. Despite this situation, on the other side, this study generally demonstrates the strong potential of UAV technology for fit-for-purpose cadastral mapping for coastline settlements, offering advantages in terms of geometric reliability, cost-effectiveness, and reduced data acquisition time. This raises another open research question: *"How can UAV technology be fully integrated into the existing national land policy framework?"* Future research needs to focus on reengineering land administration business processes (e.g., land registration, redistribution, monitoring, conflict resolution, taxation, consolidation, valuation, and development) to include UAV-derived data and technology. This includes the analysis of human resources, legal, institutional, technical, and infrastructure aspects for seamless integration into the current national system.
3. In the valuation model, although the R^2 value of 0,741 indicates that the model explains a substantial portion of the variability in the dependent variable, the presence of a Standard Error of 0,38231 suggests that some variability remains unaccounted for. This brings an open research question: *"How can the model be improved to better account for the unexplained variability?"* and the future research will be about enhancing the model's predictive accuracy by considering exploring additional independent variables that may better capture the unexplained variability or examining their interaction effects. Conducting research using more rigorous methods and adding the factual validation test (compare the result with recents transactions data, if applicable) will be an alternative too. However, considering that the primary objective of this valuation technique development is to develop a user-friendly valuation process and just fit-for-purpose by using context-sentitive variables, the open research question should also be, *"What are the most effective methods of communicating uncertainty in land valuation results?"*. Future reseaches to answer this will be about the investigation of visual uncertainty interpretation (e.g., uncertainty maps, error bars, probabilistic heatmaps) and the narratives, indices, or scenario reports of uncertainty, which is making the uncertainty tangible to decision-makers.
4. Indonesia is a vast country with numerous coastal settlements outside the Riau Islands. Unique local culture, wisdom and legal systems, economic drivers, environmental characteristics, and historical land use patterns shape the settlements. This raises the question: *"What are the key challenges and enablers for developing scalable tenure arrangements, cadastral systems, and valuation models that are responsive to the geographic diversity of Indonesia's coastline?"* Future research should focus on investigating scalability. Research in other geographic regions

can help explore regional differences and identify how tenure arrangements vary across contexts. This could contribute to the development of a tenure database that is useful for policy formulation. Examining the applicability of semi-automatic edge detection and land valuation method used in different regions and environments may provide insights into the generalizability of these approaches and highlight areas requiring further customization. Such research would help identify regional factors that affect the effectiveness of these methods and support the creation of more universally applicable solutions.

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8 APPENDICES

Appendix 1	Distribution of coastal settlements in Riau Island
Appendix 2	AHP questionnaire
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Appendix 1. Distribution of coastline settlements in Riau Island Province

City/ Regency	Locations	No of settlements	Name	Coordinates (Lat, Long)	Estimation of the area covered by buildings (m2)	Estimation of the area covered by buildings (ha)	Common size area of the buildings (m2)	Estimation number of buildings
Batam City (71 locations)	Terong Island	1	Terong	0,946963;103,765859	38.533,27	3,85	109	354
	Bakau Island	2	Bakau 1	0,947084;103,773585	23.955,94	2,40	107	224
			Bakau 2	0,938777;103,776437	42.248,58	4,22	124	341
	Geranting Island	1	Geranting	0,976898;103,772970	43.627,41	4,36	80,4	543
	Katumba Island	1	Katumba	0,964731;103,792017	11.453,64	1,15	93	123
	Sali Island	1	Sali	1,018885;103,803385	3.925,35	0,39	96	41
	Buntong Island	1	Buntong Island	1,044105;103,795113	6.656,33	0,67	119	56
	Pemping Island	1	Pemping Island	1,085566;103,808864	17.063,44	1,71	113	151
	Labon Besar Island	1	Labon Besar	1,096716;103,780657	14.523,24	1,45	81	179
	Semakau Kecil Island	1	Semakau Kecil	1,101373;103,824244	2.033,86	0,20	71	29
	Kasu Island	2	Kasu 1	1,073827;103,819344	6.959,33	0,70	106	66
			Kasu 2	1,068127;103,826438	88.923,48	8,89	113	787
	Kasu Kecil Island	1	Kasu Kecil	1,071713;103,827773	8.888,39	0,89	102	87
	Piring Island	1	Piring	1,106848;103,845083	1.699,77	0,17	73	23

	Cukus Sarang Island	1	Cukus Sarang	1,112059;103,847511	34.995,52	3,50	120	292
	Lengkang Kecil Island	1	Lengkang Kecil	1,117972;103,872210	53.856,56	5,39	124	434
	Anak Ladang Island	1	Anak Ladang	1,129262;103,879057	75.207,48	7,52	150	501
	Belakang Padang Island	5	Belakang Padang 1	1,141238; 103,879630	11.786,05	1,18	135	87
			Belakang Padang 2	1,143191;103,889255	29.454,27	2,95	170	173
			Belakang Padang 3	1,148425;103,893390	71.706,49	7,17	125	574
			Belakang Padang 4	1,156615;103,890838	115.431,98	11,54	123	938
			Belakang Padang 5	1,152317;103,881409	26.263,70	2,63	290	91
	Pecom Island	2	Pecom 1	0,998578;103,823034	28.239,33	2,82	70	403
			Pecom 2	0,998480;103,828682	5.886,32	0,59	82	72
	Bertam Island	1	Bertam	1,067537;103,869750	12.373,56	1,24	70	177
	Bertam Kecil Island	2	Bertam Kecil 1	1,069359;103,872600	9.132,70	0,91	87	105
			Bertam Kecil 2	1,070882;103,875093	7.326,55	0,73	90	81
	Gara Island	1	Gara	1,059945;103,873171	30.545,48	3,05	70	436
	Bulang Kebam Island	1	Bulang Kebam	1,017903; 103,884460	32.040,62	3,20	97	330
	Bulang Lintang Island	1	Bulang Lintang	1,020438;103,880928	5.217,56	0,52	86	61
	Gelam Island	1	Gelam	0,962749;103,849272	25.861,85	2,59	90	287
	Gelam Bawah Island	1	Gelam Bawah	0,939241;103,888732	4.482,58	0,45	88	51
	Buluh Island	1	Buluh	1,015931;103,929254	152.892,69	15,29	76	2.012

	Labu Island	1	Labu	1,003366; 103,970332	5.885,06	0,59	70	84
	Ayer Island	1	Ayer	0,984819;103,978221	15.410,16	1,54	102	151
	Tengah Kajo Island	1	Tengah Kajo	0,962492;103,979500	18.748,54	1,87	98	191
	Temoyong Island	1	Temoyong	0,933730;103,964375	33.085,01	3,31	119	278
	Selat Nenek Island	1	Selat Nenek	0,904632;103,952478	31.423,14	3,14	110	286
	Temoyong Kecil Island	1	Temoyong Kecil	0,904915;103,950758	4.741,45	0,47	84	56
	Batam Island	12	Batam 1	1,098875; 103,929399	109.737,48	10,97	130	844
			Batam 2	1,129407;103,966948	10.493,09	1,05	75	140
			Batam 3	1,145645;103,992838	4.321,18	0,43	109	40
			Batam 4	1,148565;103,999321	53.611,93	5,36	105	511
			Batam 5	1,187319;104,010039	55.298,91	5,53	86	643
			Batam 6	1,156949;104,036264	11.855,62	1,19	92	129
			Batam 7	1,035576;104,114182	4.316,65	0,43	60	72
			Batam 8	1,027214; 104,096912	21.515,49	2,15	76	283
			Batam 9	0,983363;104,098351	15.119,12	1,51	68	222
			Batam 10	0,982103;104,028480	11.653,40	1,17	69	169
			Batam 11	0,991451;104,010252	24.075,55	2,41	86	280
			Batam 12	1,008401;103,969128	16.403,23	1,64	78	210
	Kasem Island	1	Kasem	1,031302; 104,135089	8.063,62	0,81	70	115
	Pulau Kubong	1	Pulau Kubong	1,018574;104,144472	9.813,26	0,98	55	178
	Pulau Ngenang	1	Pulau Ngenang	1,022167; 104,172571	3.444,21	0,34	100	34
	Combon Island	1	Combon	0,944597; 104,194841	9.798,91	0,98	135	73
	Subang Mas Island	2	Subang Mas 1	0,918945;104,186009	9.361,16	0,94	97	97
			Subang Mas 1	0,923070;104,157935	6.534,43	0,65	74	88

	Rempang Island	2	Rempang 1	0,811935;104,228333	21.171,38	2,12	67	316
			Rempang 1	0,804358;104,215108	20.702,06	2,07	58	357
	Galang Island	1	Galang	0,794487;104,207228	21.781,76	2,18	96	227
				0,708910;104,304658	7.084,94	0,71	61	116
	Galang Baru Island	2	Galang Baru 1	0,699899;104,233296	19.483,25	1,95	65	300
			Galang Baru 1	0,686631;104,246372	10.926,62	1,09	90	121
	Karas Besar Island	2	Karas Besar 1	0,753059;104,321758	14.835,75	1,48	99	150
			Karas Besar 2	0,754112;104,340304	24.945,45	2,49	90	277
				0,744204;104,357508	11.861,79	1,19	71	167
	Sembur Karas Island	1	Sembur Karas	0,672841;104,301234	32.908,54	3,29	91	362
	Karas Islands	2	Karas 1	0,820390;104,296795	5.908,02	0,59	57	104
			Karas 2	0,819003;104,295276	8.948,85	0,89	84	107
	Abang Island	1	Abang	0,540883;104,236065	52.893,91	5,29	73	725
	Other locations	3	Other location 1	0,797421;104,209543	4.028,34	0,40	63	64
			Other location 2	0,648642;104,239718	22.154,42	2,22	80	277
			Other location 3	0,688175;104,260023	8.702,59	0,87	77	113
					1.826.241,65	***182,62***	***94,5***	***19.065***
Tanjungpinang City (19 locations)	Bintan Island (Kp. Madong)	1	Bintan (Kp. Madong)	0,976626;104,471884	5623,54	0,56	70	80
	Bintan Island (Tg. Sebaok)	1	Bintan (Tg. Sebaok)	0,976536;104,417843	6.342,71	0,63	68	93
	Bintan Island (Senggarang Besar)	1	Bintan (Senggarang Besar)	0,952766;104,423645	9.879,39	0,99	111	89
	Bintan Island (Senggarang Cina)	1	Bintan (Senggarang Cina)	0,943008;104,439104	140.346,52	14,03	153	917

	Bintan Island (Kampung Bugis)	1	Bintan (Kampung Bugis)	0,942428;104,444630	68.870,60	6,89	88	789
	Bintan Island (Sei Ladi)	1	Bintan (Sei Ladi)	0,939299;104,456437	4.865,05	0,49	93	52
	Bintan Island (Pel. Kargo Bt. 6)	1	Bintan (Pel. Kargo Bt. 6)	0,926056;104,478309	7.065,61	0,71	85	83
	Bintan Island (Kp. Bulang)	1	Bintan (Kp. Bulang)	0,929533;104,472298	5.643,13	0,56	88	64
	Bintan Island (Tg. Unggat Rawasari)	1	Bintan (Tg. Unggat Rawasari)	0,925572;104,467910	54.783,82	5,48	101	542
	Bintan Island (Tg. Unggat)	1	Bintan (Tg. Unggat)	0,927184;104,463190	20.988,41	2,10	110	191
	Bintan Island (Tg. Unggat PT. Penuin)	1	Bintan (Tg. Unggat PT. Penuin)	0,925379;104,455044	57.726,60	5,77	130	444
	Bintan Island (Kamboja)	1	Bintan (Kamboja)	0,929511;104,449387	23.3104,10	23,31	191	1.220
	Bintan Island (Pelantar Pasar)	1	Bintan (Pelantar Pasar)	0,932463;104,443867	23.6293,83	23,63	127	1.861
	Bintan Island (Teluk Keriting)	1	Bintan (Teluk Keriting)	0,915989; 104,438737	72.189,49	7,22	118	612
	Bintan Island (Dompak)	1	Bintan (Dompak)	0,876203;104,491926	4.924,80	0,49	115	43
	Bintan Island (Kelam Pagi)	1	Bintan (Kelam Pagi)	0,850066;104,484165	3.601,52	0,36	105	
	Penyengat Island	3	Penyengat 1	0,932186;104,420187	30.806,84	3,08	126	244
			Penyengat 2	0,928278;104,425890	35.900,55	3,59	128	280
			Penyengat 3	0,925704;104,417833	13.414,18	1,34	77	174
					1.012.370,71	***101,24***	***109,68***	***7.808***

Kabupaten Bintan (37 locations)	Bintan Island (Tembeling)	1	Bintan (Tembeling)	1,018983;104,470170	12.972,69	1,30	69	188
	Bintan Island (Penaga)	1	Bintan (Penaga)	1,042022;104,422788	14.197,63	1,42	75	189
	Bintan Island (Busung)	1	Bintan (Busung)	1,019933;104,336825	9.518,46	0,95	73	130
	Bintan Island (Tanjung Uban)	2	Bintan (Tanjung Uban 1)	1,057860;104,222836	25.278,54	2,53	81	312
			Bintan (Tanjung Uban 2)	1,063274;104,217319	26.515,73	2,65	241	110
	Bintan Island (Tg. Berakit)	1	Bintan (Tg. Berakit)	1,201764;104,551113	6.801,56	0,68	60	113
	Bintan Island (Teluk Sasah)	1	Bintan (Teluk Sasah)	1,106320;104,633751	4.412,05	0,44	58	76
	Bintan Island (Kawal)	2	Bintan (Kawal 1)	0,991737;104,637173	42.256,54	4,23	85	497
			Bintan (Kawal 2)	0,988360;104,635099	4.174,12	0,42	62	67
	Bintan Island (Kijang)	3	Bintan (Kijang)	0,852708;104,611067	31.310,25	3,13	201	156
				0,839102;104,609158	19.354,69	1,94	74	262
				0,833326;104,610418	35.958,95	3,60	89	404
	Bintan Island (Sungai Enam)	1	Bintan (Sungai Enam)	0,813180;104,594985	19.365,30	1,94	111	174
	Bintan Island (Batu Licin)	1	Bintan (Batu Licin)	0,830903;104,519949	7.863,14	0,79	170	46
	Dendun Island	1	Dendun	0,795358;104,505981	51.947,56	5,19	79	658
	Mantang Island	3	Mantang 1	0,791562;104,538814	8.700,63	0,87	95	92
			Mantang 2	0,793862;104,541401	8.845,99	0,88	105	84
			Mantang 3	0,793197;104,556276	13.602,58	1,36	174	78

	Senjolong Island	1	Senjolong	0,778303;104,589859	9.151,45	0,92	77	119
	Numbing Island	3	Numbing 1	0,761189;104,709041	6.909,17	0,69	105	66
			Numbing 2	0,750467;104,731671	14.377,58	1,44	102	141
			Numbing 3	0,748259; 104,740131	2.141,55	0,21	75	29
	Gin Besar Island	2	Gin Besar 1	0,761287; 104,721102	6.023,85	0,60	100	60
			Gin Besar 2	0,756141; 104,731405	2.726,91	0,27	66	41
	Kelong Kecil Island	1	Kelong Kecil	0,857920;104,616476	24.433,10	2,44	155	158
	Buton Island	1	Buton	0,877849;104,652811	17.587,05	1,76	50	352
	Kelong Island	2	Kelong 1	0,863609;104,652904	64.143,06	6,41	107	599
			Kelong 2	0,868529; 104,653174	1.785,33	0,18	78	23
	Poto Island	1	Poto	0,863282;104,661158	7.072,31	0,71	90	79
	Mapur Island	2	Mapur 1	1,002113;104,796128	56.846,82	5,68	102	557
			Mapur 2	0,959046;104,820749	5.570,32	0,56	108	52
	Tambelan Besar Island	2	Tambelan Besar 1	1,001216;107,564452	195.876,68	19,59	101	1.939
			Tambelan Besar 2	0,991522;107,560291	39.227,10	3,92	103	381
	Other locations	4	Other location 1	0,786379;104,518955	1.855,09	0,19	65	29
			Other location 2	0,864817;104,657238	5.083,89	0,51	79	64
			Other location 3	0,867211;104,655741	2.895,77	0,29	52	56
			Other location 4	0,870166;104,656316	8.118,81	0,81	50	162
					814.902,25	***81,49***	***96,41***	***8.543***
Kabupaten Karimun (35 locations)	Karimun Besar Island	4	Karimun Besar 1	0,998621;103,392009	242.121,02	24,21	168	1441
			Karimun Besar 2	0,992217;103,401792	76.702,17	7,67	150	511
			Karimun Besar 3	1,000021;103,416495	51.437,47	5,14	120	429

			Karimun Besar 4	0,992433;103,428681	145.257,63	14,53	96	1.513
	Tanjung Batu Kecil Island	1	Tanjung Batu Kecil	0,906942;103,478526	4.272,34	0,43	105	41
	Buru Island	3	Buru 1	0,899534;103,486092	3.353,86	0,34	93	36
			Buru 2	0,870241;103,497346	17.567,94	1,76	138	127
			Buru 3	0,862184;103,502408	70.786,47	7,08	123	575
	Kundur Island	1	Kundur	0,894899;103,372450	6.323,01	0,63	86	74
	Durai Island	1	Durai	0,505240;103,623520	36.260,99	3,63	144	252
	Sanglar Kecil Island	1	Sanglar Kecil	0,624812;103,639058	5.499,26	0,55	53	104
	Sanglar Besar Island	3	Sanglar Besar 1	0,626913;103,673927	5.851,78	0,59	61	96
			Sanglar Besar 2	0,613071;103,675760	3.892,44	0,39	45	86
			Sanglar Besar 3	0,615214;103,704678	5.241,02	0,52	61	86
	Sugi Bawah Island	2	Sugi Bawah 1	0,753429;103,708874	63.075,80	6,31	162	389
			Sugi Bawah 2	0,758421;103,725928	18.597,86	1,86	199	93
	Jang Island	2	Jang 1	0,754622;103,720772	16.147,02	1,61	109	148
			Jang 2	0,750106;103,728810	31.103,45	3,11	90	346
	Pauh Island	2	Pauh 1	0,795025;103,709260	3.453,67	0,35	76	45
			Pauh 2	0,794236;103,714664	29.720,43	2,97	85	350
	Sugi Island	5	Sugi 1	0,869392;103,717962	6.538,94	0,65	118	55
			Sugi 2	0,879484;103,762760	9.865,65	0,99	72	137
			Sugi 3	0,862744;103,789774	8.897,42	0,89	124	72
			Sugi 4	0,831006;103,817277	9.100,97	0,91	76	120
			Sugi 5	0,787236;103,832523	17.678,72	1,77	158	112
	Keban Island	2	Keban 1	0,881478;103,767340	20.907,72	2,09	199	105
			Keban 2	0,874574;103,774493	16.942,26	1,69	135	125

	Pasai Island	1	Pasai	0,884194;103,761979	10.683,02	1,07	94	114
	Combol Island	2	Combol 1	0,818831;103,863728	16.887,64	1,69	97	174
			Combol 2	0,800320;103,884963	22.318,32	2,23	98	228
	Citlim Island	1	Citlim	0,775980;103,936590	14.907,47	1,49	99	151
	Other locations	1	Other locations	0,837467;103,700123	10.184,55	1,02	128	80
					1.001.578,30	***100,16***	***111,31***	***8.215***
Kabupaten Lingga (42 locations)	Mesanak Island	3	Mesanak 1	0,403774;104,521224	12.187,02	1,22	191	64
			Mesanak 2	0,403488;104,528277	3.573,50	0,36	101	35
			Mesanak 3	0,373922;104,527106	18.864,88	1,89	63	299
	Benan Island	3	Benan 1	0,437901;104,396664	5.137,07	0,51	74	69
			Benan 2	0,447132;104,429827	9.881,73	0,99	133	74
			Benan 3	0,470512;104,451941	45.963,85	4,60	118	390
	Duyung Island	1	Duyung	0,360895;104,472633	19.200,93	1,92	126	152
	Medang Island	1	Medang	0,369081;104,420601	32.288,69	3,23	130	248
	Temiang Island	1	Temiang	0,310512;104,418459	17.155,15	1,72	127	135
	Rejai Island	1	Rejai	0,167051;104,487045	29.670,54	2,97	208	143
	Mamut Islands	3	Mamut 1	0,125537;104,501128	21.211,86	2,12	126	168
			Mamut 2	0,123544;104,492966	32.902,42	3,29	128	257
			Mamut 3	0,076935;104,559255	6.346,58	0,63	67	95
	Singkep Island	3	Singkep 1	-0,534750;104,317762	49.664,78	4,97	135	368
			Singkep 2	-0,426972;104,271761	22.229,35	2,22	88	253
			Singkep 3	-0,343238;104,461884	7.509,97	0,75	53	142

	Rusuk Buaya Island	1	Rusuk Buaya	-0,356830;104,171038	37.882,58	3,79	103	368
	Posik Island	3	Posik 1	-0,372508;104,172234	8.709,35	0,87	95	92
			Posik 2	-0,374577;104,175661	6.980,02	0,70	88	79
			Posik 3	-0,380065;104,180527	24.363,16	2,44	91	268
	Selajar Island	2	Selajar 1	-0,324463;104,460799	23.271,83	2,33	161	145
			Selajar 2	-0,315347;104,465081	8.855,74	0,89	50	177
	Lingga Island	6	Lingga 1	-0,005691;104,533148	11.817,74	1,18	58	204
			Lingga 2	-0,014659;104,609082	16.579,39	1,66	68	244
			Lingga 3	-0,079536;104,638841	190.454,59	19,05	112	1.700
			Lingga 4	-0,104527;104,650712	22.055,27	2,21	125	176
			Lingga 5	-0,203189;104,784855	21.497,81	2,15	147	146
			Lingga 6	-0,241667;104,467421	7.949,16	0,79	98	81
	Bujang Island	1	Bujang	-0,138575;104,912825	9.543,33	0,95	55	174
	Sebangka Island	2	Sebangka 1	0,109287;104,571916	11.287,49	1,13	50	226
			Sebangka 2	0,036774;104,708882	16.394,04	1,64	54	304
	Senayang Island	1	Senayang	0,040403; 104,652857	83.762,07	8,38	92	910
	Tapai Island	1	Tapai	-0,370713;104,269902	4.636,15	0,46	60	77
	Bakung Island	3	Bakung 1	0,091724;104,404537	17.677,61	1,77	75	236
			Bakung 2	0,042531;104,474465	11.720,08	1,17	71	165
			Bakung 3	0,017176;104,494333	35.753,39	3,58	60	596
	Other locations	5	Other location 1	0,236784;104,447479	12.528,31	1,25	110	114
			Other location 2	0,218153;104,386381	5.727,55	0,57	78	73
			Other location 3	0,212540;104,392591	27.844,84	2,78	140	199
			Other location 4	-0,152530;104,750596	6.508,82	0,65	84	77
			Other location 5	-0,076679;104,851704	33.304,10	3,33	115	290

					1.011.398,32	***101,14***	***100,20***	***10.013***
Kabupaten Kepulauan Anambas (63 locations)	Jemaja Island	11	Jemaja 1	3,030073;105,715555	1.968,16	0,20	58	34
			Jemaja 2	3,005384;105,691693	3.426,84	0,34	70	49
			Jemaja 3	2,991168;105,702804	158.561,98	15,86	141	1.125
			Jemaja 4	2,983916;105,714152	28.040,87	2,80	104	270
			Jemaja 5	2,975907;105,713588	18.700,03	1,87	94	199
			Jemaja 6	2,962518;105,715082	44.571,45	4,46	104	429
			Jemaja 7	2,962299;105,707982	9.211,32	0,92	89	103
			Jemaja 8	2,908679;105,701135	25.465,27	2,55	82	311
			Jemaja 9	2,867298;105,747460	7.909,97	0,79	47	168
			Jemaja 10	2,907298;105,784227	25.237,60	2,52	95	266
			Jemaja 11	2,909707;105,799719	75.772,63	7,58	94	806
	Keramut Island	1	Keramut	3,095494;105,652314	27.919,64	2,79	103	271
	Mubur Island	5	Mubur 1	3,316765;106,199052	8.610,29	0,86	83	104
			Mubur 2	3,322940;106,200114	26.319,11	2,63	109	241
			Mubur 3	3,322253;106,205441	4.983,41	0,50	49	102
			Mubur 4	3,307264;106,221454	40.351,98	4,04	82	492
			Mubur 5	3,321938;106,228621	29.361,68	2,94	75	391
	Matak Island	13	Matak 1	3,322291;106,240578	17.893,18	1,79	77	232
			Matak 2	3,335777;106,263802	76.195,68	7,62	99	770
			Matak 3	3,346609;106,267109	30.897,83	3,09	105	294
			Matak 4	3,358408; 106,295247	4.204,43	0,42	64	66

			Matak 5	3,344064;106,291463	79.361,11	7,94	88	902
			Matak 6	3,331927;106,297160	224.823,01	22,48	100	2.248
			Matak 7	3,306357;106,288936	33.579,80	3,36	100	336
			Matak 8	3,290780;106,291973	36.391,31	3,64	135	270
			Matak 9	3,273877;106,279634	13.795,71	1,38	90	153
			Matak 10	3,296375;106,274132	33.057,44	3,31	116	285
			Matak 11	3,273592;106,264215	27.263,80	2,73	137	199
			Matak 12	3,257521;106,265891	46.769,85	4,68	201	233
			Matak 13	3,247102;106,280656	62.925,27	6,29	98	642
	Munjan Island	2	Munjan 1	3,079798;106,348355	29.243,30	2,92	116	252
			Munjan 2	3,058672;106,344085	2.457,17	0,25	57	43
	Mengkait Island	1	Mengkait	2,905462;106,133652	7.665,52	0,77	37	207
	Siantan Kecil Island	1	Siantan Kecil	3,118155;106,116475	9.939,26	0,99	87	114
	Telaga Island	2	Telaga 1	3,062110;105,968664	11.729,90	1,17	127	92
			Telaga 2	3,041999;105,967868	8.738,35	0,87	68	129
	Telaga Kecil Island	2	Telaga Kecil 1	3,085957;105,953699	10.580,58	1,06	74	143
			Telaga Kecil 2	3,081970;105,953027	2.711,79	0,27	93	29
	Siantan Island	9	Siantan 1	3,214049;106,217545	158.896,19	15,89	140	1.135
			Siantan 2	3,228530;106,233905	27.799,45	2,78	139	200
			Siantan 3	3,221676;106,238570	45.604,30	4,56	133	343
			Siantan 4	3,206214;106,259189	46.171,14	4,62	133	347
			Siantan 5	3,175812;106,273740	47.304,85	4,73	121	391
			Siantan 6	3,112026;106,262362	18.793,70	1,88	61	308
			Siantan 7	3,115917;106,253767	4.242,13	0,42	80	53
			Siantan 8	3,107449;106,239254	2.775,10	0,28	67	41

			Siantan 9	3,171366;106,209215	8.366,96	0,84	119	70
	Bajau Island	8	Bajau 1	3,124629;106,335180	11.956,65	1,20	96	125
			Bajau 2	3,124646;106,330722	49.510,73	4,95	65	762
			Bajau 3	3,118570; 106,329113	13.011,33	1,30	55	237
			Bajau 4	3,096947;106,308241	7.515,54	0,75	52	145
			Bajau 5	3,092720; 106,314761	3.088,26	0,31	89	35
			Bajau 6	3,100535; 106,316516	4.078,18	0,41	51	80
			Bajau 7	3,110976;106,291851	6.369,24	0,64	46	138
			Bajau 8	3,140303; 106,299916	12.742,70	1,27	58	220
	Other locations	7	Other location 1	3,090796;105,699741	7.404,92	0,74	51	145
			Other location 2	3,086642;105,724317	29.890,64	2,99	46	650
			Other location 3	3,278324;106,301473	17.427,35	1,74	72	242
			Other location 4	3,249927;106,302675	24.569,96	2,46	91	270
			Other location 5	3,247123;106,295357	89.827,45	8,98	70	1.283
			Other location 6	3,234123;106,288153	5.854,72	0,59	90	65
			Other location 7	3,086955;106,334479	4.019,77	0,40	63	64
					1.953.857,81	***195,39***	***89,29***	***20.347***
Kabupaten Natuna	Laut Island	2	Laut 1	4,699804;107,946156	36.417,11	3,64	154	236
39 locations			Laut 2	4,738556;107,997105	74.099,45	7,41	167	444
	Seluan Island	1	Seluan	4,118349; 107,847645	11.464,05	1,15	53	216
	Bunguran Island	10	Bunguran 1	3,988852;107,989739	15.663,28	1,57	129	121
			Bunguran 2	4,105246;108,250856	4.324,06	0,43	47	92
			Bunguran 3	3,951023;108,395526	29.594,78	2,96	146	203
			Bunguran 4	3,945376;108,393702	60.625,27	6,06	113	537
			Bunguran 5	3,894202;108,389221	36.023,12	3,60	138	261

			Bunguran 6	3,725189;108,126516	17.303,15	1,73	112	154
			Bunguran 7	3,733241;108,148683	13.488,63	1,35	87	155
			Bunguran 8	3,809476;108,239919	10.718,33	1,07	66	162
			Bunguran 9	3,811839;108,184769	14.241,43	1,42	95	150
			Bunguran 10	3,988852;107,989739	15.663,28	1,57	129	121
	Salor Island	1	Salor	3,887434;107,917311	29.988,00	3,00	67	448
	Sedanau Island	4	Sedanau 1	3,803904;108,015180	5.135,89	0,51	71	72
			Sedanau 2	3,803553;108,030232	68.311,54	6,83	125	546
			Sedanau 3	3,793762;108,032739	343.218,81	34,32	280	1.226
			Sedanau 4	3,785680;108,030620	78.150,16	7,82	94	831
	Batang Island	5	Batang 1	3,656537;108,050831	12.531,19	1,25	57	220
			Batang 2	3,665162;108,063442	10.144,50	1,01	80	127
			Batang 3	3,663504;108,074916	6.127,35	0,61	76	81
			Batang 4	3,637119;108,083396	83.223,86	8,32	200	416
			Batang 5	3,638116;108,057029	14.757,63	1,48	82	180
	Lagong Island	6	Lagong 1	3,613689;108,083402	49.111,94	4,91	127	387
			Lagong 2	3,634515;108,111434	25.489,22	2,55	132	193
			Lagong 3	3,624341;108,124039	32.449,65	3,24	103	315
			Lagong 4	3,596811;108,090279	14.864,85	1,49	93	160
			Lagong 5	3,597412;108,085183	38.110,43	3,81	122	312
			Lagong 6	3,596411;108,069909	19.621,22	1,96	94	209
	Sededap Island	2	Sededap 1	3,588318;108,045195	21.163,04	2,12	108	196
			Sededap 1	3,573509;108,046914	26.778,32	2,68	102	263
	Midai Island	1	Midai	3,008025;107,753119	6.417,18	0,64	122	53
	Subi Kecil Island	1	Subi Kecil	3,014043;108,864648	19.104,56	1,91	157	122

	Subi Besar Island	1	Subi Besar	3,011214;108,865170	9.251,58	0,93	107	86
	Batu Berlian Island	1	Batu Berlian	2,494181;108,955463	25.202,50	2,52	63	400
	Serasan Island	7	Serasan 1	2,496125;109,009119	26.675,99	2,67	90	296
			Serasan 2	2,506054;109,016878	14.397,80	1,44	81	178
			Serasan 3	2,510669;109,023857	70.631,11	7,06	122	579
			Serasan 4	2,502650;109,051353	47.216,26	4,72	55	858
			Serasan 5	2,501978;109,056410	21.905,52	2,19	80	274
			Serasan 6	2,497789;109,067828	14.142,74	1,41	67	211
			Serasan 7	2,497448;109,072902	20.525,76	2,05	108	190
					1.494.274,53	***149,43***	***107,1667***	***12.282***

Appendix 2. AHP Questionaire

Dear respondent,

My name is Faus Tinus Handi Feryandi, a doctoral student at the Center for Development Studies (ZEF) University of Bonn. I am currently doing a research about land tenure security in the shoreline area of Kepulauan Riau Province, Indonesia. In my fieldwork, I need some information from you through a questionnaire survey.

The questionnaire aims to know your preferences regarding what type of secured condition you desire. .

All information produced from this survey are confidential and used for research purpose.

I am thankful if you are willing to answer the questions according to the given guidance.

Sincerely yours,

Faus Tinus Handi Feryandi
Junior researcher/PhD student
Center for Development Studies (ZEF) University of Bonn Germany
Walter-Flex Str. 3 D-53113 Bonn Germany
faustinushandi@mail.uni-bonn.de
faustinushandi@yahoo.com
Mobile (ID) : 081328888909

RESPONDENT INFORMATION

Name :

Village :

Occupation :

CRITERIA AND SUB CRITERIA

No	Cluster (criteria)	Sub criteria	
A	Convenience in using land	A1	Convenience to use land for various type of usage
		A2	Convenience to install housing and its facilities
		A3	Convenience to run aquaculture activities
		A4	Convenience to install commercials buildings
B	Convenience in transferring land	B1	Possibility in inheritance
		B2	Easiness in transaction with Indonesian
		B3	Easiness in transaction with foreigners
C	Duration	C1	Unlimited time of occupation
		C2	Long period of occupation and usage (>10 to until the maximum period allowed by the regulations)

		C3	Short period of occupation and usage (max 10 years)
D	Accessibility and opportunity	D1	Higher possibility to access credit from bank
		D2	Higher prices in transactions and compensation
		D3	Easier access to get developmental supports/aid (e.g., electricity, clean water, road infrastructure, public buildings, fishing facilities, etc.) from the government/other institutions
E	Recognition	E1	Administrative recognition in a residence card or other administration documents
		E2	Recognition in the legal documents of the land (e.g., certificates, permits, deeds, contracts) by the tenure authoritative bodies
		E3	Recognition by neighborhoods
F	Security	F1	No fear of/minimum/no evictions and land expropriation
		F2	No fear of/minimum/no of potential disputes

I. PAIRWISE COMPARISON BETWEEN CRITERIA

GUIDANCE:

1. Please choose between LEFT ELEMENT and RIGHT ELEMENT that you consider more important than another by giving a cross sign (X) or checked mark (✓) in the box ☐
2. Inside the Scale row, please indicate your choice's importance by crossing or circling no 1 to 9. 9.
3. In the table below is the definition of scale 1 to 9.

Intensity of importance (values)	DEFINITION	EXPLANATION
1	Equally importance	Two options are equally preferred
3	Moderately importance	One option is moderately preferred over another
5	Strongly importance	One option is strongly preferred over another
7	Very strong importance	One option is preferred very strongly over another
9	Extremely importance	One option is completely preferred over another
2,4,6,8	Intermediate values	The grades that can be used to express intermediate values used to represent compromises between the adjacent intensity/judgments

4. By referring the above table, if you consider that LEFT ELEMENT is moderately preferred over RIGHT ELEMENT, you may put an X sign or encircle number 3.

5. If you consider that LEFT ELEMENT is equally preferred with RIGHT ELEMENT, instead of giving a cross sign (X) or a checked mark (✓) in the box ☐, you should encircle number 3.

A. CONVENIENCE IN USING LAND

Considering **Convenience in using land***, between LEFT ELEMENT and RIGHT ELEMENT, which one is more important than another?*

LEFT ELEMENT	RIGHT ELEMENT
Convenience to use land for various type of usage ☐	Convenience to install housing and its facilities ☐
Scale 1 2 3 4	5 6 7 8 9

LEFT ELEMENT	RIGHT ELEMENT
Convenience to use land for various type of usage ☐	Convenience to run aquaculture activities ☐
Scale 1 2 3 4	5 6 7 8 9

LEFT ELEMENT	RIGHT ELEMENT
Convenience to use land for various type of usage ☐	Convenience to install commercials buildings ☐
Scale 2 3 4	5 6 7 8 9

LEFT ELEMENT	RIGHT ELEMENT
Convenience to install housing and its facilities ☐	Convenience to run aquaculture activities ☐
Scale 1 2 3 4	5 6 7 8 9

LEFT ELEMENT	RIGHT ELEMENT
Convenience to install housing and its facilities ☐	Convenience to install commercials buildings ☐
Scale 1 2 3 4	5 6 7 8 9

LEFT ELEMENT	RIGHT ELEMENT
Convenience to run aquaculture activities ☐	Convenience to install commercials buildings ☐
Scale 1 2 3 4	5 6 7 8 9

B. CONVENIENCE IN TRANSFERRING LAND

*In terms of **Convenience in transferring**, between LEFT ELEMENT and RIGHT ELEMENT, which one is more important than another?*

LEFT ELEMENT					RIGHT ELEMENT				
Possibility in inheritance				☐	Easiness in transaction with Indonesian				☐
Scale	1	2	3	4	5	6	7	8	9

LEFT ELEMENT					RIGHT ELEMENT				
Possibility in inheritance				☐	Easiness in transaction with foreigners				☐
Scale	1	2	3	4	5	6	7	8	9

LEFT ELEMENT					RIGHT ELEMENT				
Easiness in transaction with Indonesian				☐	Easiness in transaction with foreigners				☐
Scale	1	2	3	4	5	6	7	8	9

C. DURATION

*In terms of **Duration**, between LEFT ELEMENT and RIGHT ELEMENT, which one is more important than another?*

LEFT ELEMENT					RIGHT ELEMENT				
Unlimited time of occupation				☐	Long period of occupation and usage (>10 to until the maximum period allowed by the regulations)				☐
Scale	1	2	3	4	5	6	7	8	9

LEFT ELEMENT					RIGHT ELEMENT				
Unlimited time of occupation				☐	Short period of occupation and usage (max 10 years)				☐
Scale	1	2	3	4	5	6	7	8	9

LEFT ELEMENT					RIGHT ELEMENT				
Long period of occupation and usage (>10 to until the maximum period allowed by the regulations)				☐	Short period of occupation and usage (max 10 years)				☐
Scale	1	2	3	4	5	6	7	8	9

D. ACCESSIBILITY AND OPPORTUNITY

*In terms of **Accessibility and opportunity**, between LEFT ELEMENT and RIGHT ELEMENT, which one is more important than another?*

LEFT ELEMENT					RIGHT ELEMENT				
Higher possibility to access credit				☐	Higher prices in transactions and compensation				☐
Scale	1	2	3	4	5	6	7	8	9

LEFT ELEMENT		RIGHT ELEMENT	
Higher possibility to access credit	☐	Easier access to get developmental supports/aid	☐
Scale 1 2 3 4		5 6 7 8 9	

LEFT ELEMENT		RIGHT ELEMENT	
Higher prices in transactions and compensation	☐	Easier access to get supports/aid from the government	☐
Scale 1 2 3 4		5 6 7 8 9	

E. RECOGNITION

*In terms of **Recognition**, between LEFT ELEMENT and RIGHT ELEMENT, which one is more important than another?*

LEFT ELEMENT		RIGHT ELEMENT	
Administrative recognition in a residence card or other administration documents	☐	Recognition in the legal documents of the land (e.g., certificates, permits, deeds, contracts) by the tenure authoritative bodies	☐
Scale 1 2 3 4		5 6 7 8 9	

LEFT ELEMENT		RIGHT ELEMENT	
Administrative recognition in a residence card or other administration documents	☐	Recognition by neighborhoods	☐
Scale 1 2 3 4		5 6 7 8 9	

LEFT ELEMENT		RIGHT ELEMENT	
Recognition in the legal documents of the land (e.g., certificates, permits, deeds, contracts) by the tenure authoritative bodies	☐	Recognition of by neighborhoods	☐
Scale 1 2 3 4		5 6 7 8 9	

F. SECURITY

*In terms of **Security**, between LEFT ELEMENT and RIGHT ELEMENT, which one is more important than another?*

LEFT ELEMENT		RIGHT ELEMENT	
No fear of/minimum/no evictions and land expropriation	☐	No fear of/minimum/ no potential disputes	☐
Scale 1 2 3 4		5 6 7 8 9	

==

II. RANKING OF THE CRITERIA

Please order the land tenure security criteria by assign numbers according to its importance.

Encircle the chosen number in the SCALE OF IMPORTANCE column.

1 = Least important
2 = Less important
3 = Important
4 = Very important
5 = Very highly important
6 = Most important

	KRITERIA	IMPORTANCE LEVEL					
A	Convenience in using land	1	2	3	4	5	6
B	Convenience in transferring land	1	2	3	4	5	6
C	Duration of tenure	1	2	3	4	5	6
D	Accessibility and opportunity	1	2	3	4	5	6
E	Recognition	1	2	3	4	5	6
F	Security	1	2	3	4	5	6

==== THANK YOU FOR YOUR WILLINGNESS TO ANSWER ====

==
==

Appendix 3. AHP calculation result

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Criteria A

Matrix

	A1	A2	A3	A4
A1	1,00000	0,97629	1,70533	2,39785
A2	1,02429	1,00000	1,96296	2,44032
A3	0,59183	0,50944	1,00000	1,47706
A4	0,41704	0,40978	0,67702	1,00000
TOTAL	3,03317	2,89551	5,34530	7,31524

Normalized matrix

	A1	A2	A3	A4	Total	Weight vector (Eigen vector)	Weighted sum vector	Consistency vector
A1	0,32969	0,33717	0,31903	0,32779	1,31368	0,32842	1,31536	4,00510
A2	0,33770	0,34536	0,36723	0,33359	1,38388	0,34597	1,38625	4,00684
A3	0,19512	0,17594	0,18708	0,20192	0,76006	0,19001	0,76092	4,00452
A4	0,13749	0,14152	0,12666	0,13670	0,54238	0,13559	0,54298	4,00442

PRINCIPAL EIGEN VALUE (λmax)	4,00522
CONSISTENCY INDEX (CI)	0,00174
CI = (λmax -n)/(n-1)	
CONSISTENCY RATIO (CR)	0,00193
CR = CI/RI	(CONSISTENT)
untuk n = 4, RI = 0,9	< 0,1

==

Criteria B

Matrix

	B1	B2	B3
B1	1,00000	2,07393	3,06785
B2	0,48218	1,00000	3,06306
B3	0,32596	0,32647	1,00000
TOTAL	1,80814	3,40040	7,13091

Normalized matrix

	B1	B2	B3	Total	Weight vector (Eigen vector)	Weighted sum vector	Consistency vector
B1	0,55305	0,60991	0,43022	1,59318	0,39830	1,23120	3,09118
B2	0,26667	0,29408	0,42955	0,99030	0,24758	0,75858	3,06404
B3	0,18027	0,09601	0,14023	0,41652	0,10413	0,31478	3,02301

PRINCIPAL EIGEN VALUE (λmax)	3,05941
CONSISTENCY INDEX (CI)	0,02970
CI = (λmax -n)/(n-1)	
CONSISTENCY RATIO (CR)	0,05121
CR = CI/RI	(CONSISTENT)
untuk n = 3, RI = 0,56	< 0,1

==

Criteria C

Matrix

	C1	C2	C3
C1	1,00000	2,78648	2,96917
C2	0,35888	1,00000	2,51453
C3	0,33679	0,39769	1,00000
TOTAL	1,69567	4,18417	6,48370

Normalized matrix

	C1	C2	C3	Total	Weight vector (Eigen vector)	Weighted sum vector	Consistency vector
C1	0,58974	0,66596	0,45794	1,71364	0,42841	1,34497	3,13945
C2	0,21164	0,23900	0,38782	0,83846	0,20962	0,64493	3,07671
C3	0,19862	0,09505	0,15423	0,44790	0,11197	0,33962	3,03303

PRINCIPAL EIGEN VALUE (λmax)	3,08306
CONSISTENCY INDEX (CI)	0,04153
CI = (λmax -n)/(n-1)	
CONSISTENCY RATIO (CR)	0,07161
CR = CI/RI	(CONSISTENT)
untuk n = 3, RI = 0,56	< 0,1

==

Criteria D

Matrix

	D1	D2	D3
D1	1,00000	1,62124	0,60734
D2	0,61507	1,00000	0,73006
D3	1,64654	1,36976	1,00000
TOTAL	3,26161	3,99100	2,33739

Normalized matrix

	D1	D2	D3	Total	Weight vector (Eigen vector)	Weighted sum vector	Consistency vector

D1	0,30660	0,25983	0,25983	0,82627	0,20657	0,72991	3,53352
D2	0,18858	0,31234	0,31234	0,81326	0,20331	0,56323	2,77025
D3	0,50482	0,34321	0,42783	1,27586	0,31897	0,93758	2,93943

PRINCIPAL EIGEN VALUE (λmax) 3,08107
CONSISTENCY INDEX (CI) 0,04053
CI = (λmax -n)/(n-1)
CONSISTENCY RATIO (CR) 0,06988
CR = CI/RI (CONSISTENT)
untuk n = 3, RI = 0,56 < 0,1

===

Criteria E

Matrix

	E1	E2	E3
E1	1,00000	1,22387	1,18379
E2	0,81708	1,00000	1,35082
E3	0,84475	0,81708	1,00000
TOTAL	2,66183	3,04095	3,53460

Normalized matrix

	E1	E2	E3	Total	Weight vector (Eigen vector)	Weighted sum vector	Consistency vector
E1	0,37568	0,40246	0,33491	1,11306	0,27826	0,84690	3,04351
E2	0,30696	0,32884	0,38217	1,01798	0,25449	0,77531	3,04649
E3	0,31736	0,26869	0,28292	0,86897	0,21724	0,66025	3,03923

PRINCIPAL EIGEN VALUE (λmax) 3,04308
CONSISTENCY INDEX (CI) 0,02154
CI = (λmax -n)/(n-1)
CONSISTENCY RATIO (CR) 0,03713
CR = CI/RI (CONSISTENT)
untuk n = 3, RI = 0,56 < 0,1

===

Criteria F

Normalized matrix

	E1	E2	Total	Weight vector (Eigen vector)	Weighted sum vector	Consistency vector
E1	0,55033	0,55033	1,10067	0,27517	0,55033	2,00000
E2	0,44967	0,44967	0,89933	0,22483	0,44967	2,00000

PRINCIPAL EIGEN VALUE (λmax)	2,00000
CONSISTENCY INDEX (CI)	0,00000
CI = (λmax -n)/(n-1)	
CONSISTENCY RATIO (CR)	0,00000
CR = CI/RI	(CONSISTENT)
untuk n = 3, RI = 0,00	< 0,1

==

Appendix 4. Heuristic evaluation of applicability

Tenure by Numpang Bangun or Bagi Pakai system (NB)

Characteristics and descriptions of the NB system against criteria	Evaluation of subcriteria	
Convenience in using land (A) In personal interviews, according to Bapak Budi, the Head of Klam Pagi Village and Pak Dona from Penyengat Island, land tenure through the NB system was mainly for housing purposes. Other purposes, such as making ponds, fish farms, or commercial businesses and restaurants, are not recommended, but they are still possible with further agreements with the member of the community.	A1	F
	A2	VG
	A3	F
	A4	F
Convenience in transferring land (B) In general, according to Indonesian common land law, land transfer (Indonesian: "peralihan hak") activities are made possible by two events, namely legal events and legal actions (Santoso, 2010). Legal events refer to any occurrences within a society that carry legal implications related to land rights, such as a death that results in a bequest. A legal action is an act by a legal subject that has legal consequences; those legal consequences are desired by the respected legal subjects. According to Santoso, examples of legal actions are buying and selling, leasing, grants (hibah), auctions (lelang), exchange (tukar guling), and participation as capital of company investment (penyertaan modal perusahaan). Those who hold the land through the NB system can easily inherit the land to the children or grandsons without any process apart from an informal agreement. However, he is prohibited from engaging in legal transactions such as buying and selling to other parties, whether they are fellow Indonesian citizens or foreigners. Also, NB cannot be transferred through other legal acts of grants, auctions, exchanges, and investment participation.	B1	VG
	B2	VP
	B3	VP
Duration (C)	C1	VG
	C2	G

Landholding through this system can last with no limited time. The community permits the holders to occupy and use the land for their purposes for as long as they need.	C3	F
Accessibility and opportunity (D) Because the proof of possession is only coming from the oral agreement or in an informal paper from the head of the hamlet of the community, the land cannot be a mortgage for a loan from the bank or other formal financial institutions such as Credit Union. From the results of our discussion with the Head of Klam Pagi, it was revealed that the bank would certainly refuse their submission even though they showed some evidence, for example, a KTP (ID/residence card), photographs, or proof of physical possession that they had lived on the land for a long time. In the case of a development project that requires land acquisition or land procurement, the compensation provided by the project implementor is usually only in the form of "mercy money". The amount is less than the compensation based on the market value estimated by a professional or government appraiser. However, the landholders can still get support from the government in the community empowerment programs, for example, for house renovation programs and infrastructure supports such as pelantar roads construction, electricity, and clean water supply.	D1	VP
	D2	F
	D3	F
Recognition (E) Those who occupy land through the NB system can get a KTP/residence card indicating the location of their residence. This situation shows the recognition of the existence of that piece of land in the state administration system. The village administration respects this tenure form, despite the lack of formal recognition from land administration authorities (i.e., Land Office) regarding the control of their land through land certificates. The neighbors fully acknowledge their possession of the land, even without formal documents, because it is a family or community system for landholding.	E1	G
	E2	F
	E3	VG
Security (F) A kind of tenure form like NB system can be said to be insufficient in the modern era against the possibility of land grabbing or land expropriation. The system does not provide legal and formal security due to the absence of written evidence issued by the Land Office. A tenure that relies on the verbal agreement only, even though the physical occupation will not be a problem, is still average from a juridical point of view that makes the legal strength lacking. In other words, in terms of state administration affairs, the position of landholders is not quite stable. If there are claims from other parties, for example, from investors/private parties that want to do physical land development in the area and require land expansion, the landholders' bargaining position is not solid. The boundary of NB system tenure is not based on official technical surveys and measurements, only created by estimation. It is also not published in a paper. It makes the legitimacy of the land of the NB system boundary is less stronger the surveyed boundary. However, due to the solid recognition from neighbors, land problems such as boundary overlap and rights claims among the community members are very rare. So, it can be said that this NB system, although it cannot formally give protection against land expropriation, in terms of land dispute prevention inside the neighborhood, can establish an effective secure situation.	F1	F
	F2	G

***

Tenure by Grant (GR)

Characteristics and descriptions of Grant against criteria	Evaluation	
Convenience in using land (A) No restrictions on the usage of the grant land. It is because, according to Mahadi (1976), the initial purpose of grant landholding is just permission for doing land clearance. In the current situation, those who hold grant letters usually have used their lands for intentions of housing, farm areas, fish ponds, or just left them as vacant lands.	A1	G
	A2	F
	A3	F
	A4	VP
Convenience in transferring land (B) Transferring the possession of a grant letter from one party to another is not an easy process. Even if the inheritance process is feasible, selling the entire land covered by a grant letter can be challenging for fellow Indonesians and impossible for foreigners. The main reason is that the grant letter is an old proof of possession; only its civil rights are recognized. Under current legal regulations, individuals holding a grant may need to convert it to another tenure format before initiating the transfer process. Grant landholding is not transferable to either Indonesians or foreigners through grants, exchanges, or auctions.	B1	F
	B2	VP
	B3	VP
Duration (C) Those who hold land on a grant letter basis must now report and change it into another proof of landholding to the village administration office so that their possession is still recognized. In short, it can be said that, while the claim remains valid, the grant letter is no longer able to confirm the duration of possession.	C1	VP
	C2	VP
	C3	VP
Accessibility and opportunity (D) Banks and financial institutions do not accept grant letters as collateral for loans. If there is an activity of land acquisition for the public interest, the old claims by the grant letter will usually be reviewed, so the area to be compensated decreases a lot, and compensation will only be in the form of "mercy money". The grant holders can request the infrastructure support from the government, but the opportunity is not as large as those who have other proof of possessions, such as land certificates or a letter to prove possession (SKT).	D1	VP
	D2	P
	D3	P
Recognition (E) Individuals who have the grant letter do not have problems obtaining a KTP/residence card showing that they are residing on that land. This indicates that their administrative rights to the land are respected. However, they cannot proceed with their claim on the land based on the grant letter (as an "alas hak") to the authority for getting a land certificate. "Alas hak" is the term for supporting documents used for submitting a claim for a piece of land. In the matter of recognition by the surrounding neighbors, the grant letter cannot be relied upon, mainly because currently, most people consider the letter to be outdated, and the broad area occupation brought by the letter to just a person or limited family is inappropriate in today's society.	E1	G
	E2	P
	E3	P
Security (F) Due to the time of establishment that was tens or hundreds of years ago, the claim based on Grant Letter has a higher potential to cause disputes among	F1	VP

people in Riau Islands areas. In Batam Island, for example, Himad Purelang (Coalition of Indigenous People of Rempang Galang Island) is disputing with other parties over their claim based on the Sultan Grant (Berita Satu, 2013). In our discussion with Marwan, a local fisherman from Madong Village, the grassroots disputes occurred in Senggarang and Madong areas. In the field, it is often seen that the partial parts of the grant area have already been occupied by other parties, usually in the fringe area. One additional factor besides the low trust in the grant letter itself is that, at the time of the grant establishment, the land boundaries are only determined based on natural features such as trenches, rivers, large trees, and forest boundaries. The map, which depicts the grant land's area, lacks scale. Due to changes in land use and land cover, most of the boundary lines have disappeared. So, newcomers start to occupy part of the area where the boundary is not clear. On that basis, it can be concluded that the tenure by grant letter cannot help enough to minimize the risk of illegal occupation and even land grabbing by other parties.	F2	VP

***

Tenure by informal leases or Sewa Bawah Tangan (SWBT) system

Characteristics and descriptions of SWBT system against criteria	Evaluation	
Convenience in using land (A) Tenants can use the land mostly to build houses and other building-based activities, such as a small store and food stalls. For vacant land usage, such as for fish ponds, they need permission from the landholder.	A1	G
	A2	VG
	A3	F
	A4	G
Convenience in transferring land (B) In this system, the tenure by SWBT cannot be transferred to the third parties (either domestic or the foreign party) through all mechanisms.	B1	VP
	B2	VP
	B3	VP
Duration (C) The leasing period is following the agreement between the landholder and the tenant. Generally, from the results of the discussions with the residents, there is no limitation on how long the land can be leased, but usually, the agreement is on an annual basis and renewed every year. This tenure form provides a longer duration than the short term of occupation.	C1	VP
	C2	P
	C3	F
Accessibility and opportunity (D) The land held from SWBT mechanism cannot be used as collateral. The informality of the agreement and the separation of possession between the land (belonging to the landholder) and the building (belonging to the tenant) are the reasons for it. The consideration of the tenants as temporary occupants constrains their chances of receiving a house rehabilitation or renovation program. With no legal paper in hand, if there are incoming investors or a physical development by the government, both parties can only get low compensation. During strong winds and high waves commonly occurring in Riau Island waters during the Northern Wind season (November–February), buildings and other structures (e.g., karamba, bagan) may have affected. However, compensation for the affected properties is often lower than expected. Because the prominent characteristic of the area with this SWBT tenure is the non-permanent building, the government does not prioritize the area for the usual	D1	VP
	D2	VP
	D3	VP

amenities support program (roads, electricity). However, this area is contextual for a land development program, such as land readjustment.		
Recognition (E) In most cases, the tenants can obtain a KTP/residence card. SWBT is entirely informal, so the land would not get any legal recognition document of the land from the Land Office. In the SWBT area, the recognition of the occupation by neighbors is fair, not as good as the formal tenure, but as long as the tenant can get along with society, their occupation is relatively acknowledged.	E1	G
	E2	VP
	E3	F
Security (F) As a result of the handshake agreement, the clauses of possession are subject to change. The uncertainty of occupation is high. The landholder has the right to unilaterally raise the rental price in the middle of the contract. The tenants who are unable to keep up with the increase are vulnerable to losing the right to use the land. During discussions, locals revealed that administrative issues, like tenants not paying on time, frequently lead to landholder-tenant disputes. Informality also delivers a condition without juridical support. As the legal strength of SWBT tenure is weak, the protection against external disturbance such as land expropriation is also not optimal.	F1	F
	F2	F

***

Tenure by Surat Tebas/Tebas Tebang (ST) or Letter to Slash

Characteristics and descriptions of ST against criteria	Evaluation	
Convenience in using land (A) ST only permits individuals to access and clear the land (for example, shore vegetation) for specific purposes, including fishery activities and building installation.	A1	F
	A2	G
	A3	G
	A4	VP
Convenience in transferring land (B) ▪ The landholding by ST letter can be inherited and traded to Indonesian citizens. Foreigners cannot buy the ST land. If the landholder is willing to trade the land, the ST letter cannot automatically be used as a proof of possession letter. It first needs to be replaced by a new letter called Surat Keterangan Ganti Kerugian (SKGR)/a Compensation Letter, and then to the SKT. The replacement process needs the testimony from the head of the Neighborhood Association (RT), the head of the Citizenship Association (RW), signed by the hamlet head, and finally approved by the Village Head. All of the processes make the convenience for sale is average. ▪ ST is not transferable through legal acts of grants, auctions, exchanges, and investments in a company's capital.	B1	G
	B2	F
	B3	VP
Duration (C) ▪ Although the ST letter does not indicate any duration limit, logically, from its character as a preliminary letter, the letter only delivers a short tenure. In practice, however, it often serves as a long-term claim. The locals still keep the letter to indicate their claim after tens of years. It is because, a bit	C1	F
	C2	F
	C3	F

different from the grant letter, those who hold land by an ST letter are not obliged to report and change it into another proof of landholding to the village administration office in case they do not want to sell the land through a formal way.		
Accessibility and opportunity (D) ▪ The bank does not accept the ST land in a mortgage. ▪ Because as the evidence the ST letter was established a long time ago and is not in the form land certificate, the land by ST has low bargaining power for getting high compensation in land acquisition or transactions. ▪ Although the land by ST does not get high priority, it is not obstructed in getting support from the government.	D1 D2 D3	VP P F
Recognition (E) ▪ Residing on the ST land, the landholders can obtain a KTP/residence card without restriction. ▪ Having only the ST letter means that the landholders only have the previous version of recognition from the government. ▪ Because ST letter is an old letter, on the field, the recognition from the neighbours is not optimal. It is also the cause why the conversion is necessary when the landholders want to sell the land. The problem of tenure boundary may occur, as the boundary is not defined well (i.e., no survey to determine the clear boundary, usually the boundary was made on paper).	E1 E2 E3	G P P
Security (F) ▪ Although civil rights of land tenure by Surat Tebas are still recognized, its legal strength is low so that if there is a dispute, the legal protection is less reliable. ▪ As has been said, no measurement of the area and shape of the land so that the possibility of boundary overlapping or land encroachment, is higher. The visualization of the ST land boundary in the paper is also minimal, unscaled, and usually only in the form of a sketch.	F1 F2	P P

***

Surat Keterangan Tanah/Surat Kepemilikan Tanah (SKT) or Letter of Possession

Characteristics and descriptions of SKT against criteria	Performance	
Convenience in using land (A) ▪ In Tanjungpinang and its surroundings, the SKT letter provides a free opportunity for landholders to use their land for various purposes. There are no use restrictions from the village regulations. However, a house is the primary use for the land that SKT grants.	A1 A2 A3 A4	VG VG G G
Convenience in transferring land (B) ▪ Mr. Rusli, an official in Senggarang Village, mentioned in a discussion session that the holders of SKT lands could directly bequeath the land to their children and families (Rusli, 2016, personal communication). ▪ Other Indonesians can purchase and receive the land. Foreigners cannot hold land using the SKT letter. In other words, foreign nationals are not permitted to buy and sell SKT lands. ▪ SKT's land is not available for use in exchanges, auctions, or as company capital.	B1 B2 B3	VG F VP

Duration (C) ▪ The SKT letter does not impose a time limit on the possession of a piece of land. It is indicating that the possession by SKT is more appropriate for long-duration possession rather than short-term possession (short-term possession occurs typically in the circumstances that the land is only kept for business investment and not for housing purposes).	C1	VG
	C2	G
	C3	F
Accessibility and opportunity (D) ▪ In most areas of Kepulauan Riau Province, the SKT land can be valid as collateral. However, this condition only applied to several banks owned by the government, such as BRI, Bank Mandiri, and Bank Riau Kepri. The bank from the private sector (e.g., BCA, Bank Panin, Bank BII) does not accept SKT as collateral. The value of a loan from SKT is generally 20% less than the loan from a certificated land (Ginting, 2017). ▪ In the case of compensation for development projects or a purchase, SKT lands get a high opportunity to be valued better than the lands by the grant letter, ST, NB system, and SWBT. ▪ There is no land measurement by licensed surveyors, so the area accuracy is not reliable, and hence problems are often found with the size and shape. It does not directly lead to eviction, but it may add to the possibility of inadequate compensation. ▪ The access and opportunity for SKT holders to get any development supports from the government are not impeded.	D1	G
	D2	F
	D3	F
Recognition (E) ▪ KTP/residence cards can be given without any problem to a person living in a land by SKT. ▪ The village and sub-district governments also recognize the SKT letter as an intermediate proof of land possession establishment. However, in the Indonesian land administration system, the SKT letter still functions as "alas hak", which is a supporting document for granting certificates of land rights established by Land Office. It makes its legal recognition level not as high as land certificates. In the aspect of the neighbours recognition, as the process of obtaining the SKT letter requires the involvement of adjacent neighbours, RT, RW, and village administration, the SKT landholding has high recognition from the surrounding neighbours.	E1	VG
	E2	G
	E3	VG
Security (F) ▪ Although there is no formal survey made by licensed surveyors, compared with other non-statutory forms and other informal letters, the SKT letter provides stronger claims over the land because there is also a field check by the village officials. ▪ The recognition from the surrounding area is high, so the SKT letter is considered capable of providing adequate protection from disputes from the local environment.	F1	G
	F2	G

***

The right to build or Hak Guna Bangunan (HGB)

<table>
<tr><th>Characteristics and descriptions of HGB against criteria</th><th colspan="2">Evaluation</th></tr>
<tr><td rowspan="4">Convenience in using land (A)
▪ As long as the majority of the allotment of land is for building-based usage in the context of the residential and business (service and commercial) sectors, HGB can be assigned. This characteristic often leads to the designation of HGB as a land right for commercial and investment purposes, including those in the tourism sector. According to BAL 1960, HGB does not apply to the land with the majority allotment, and utilization is for non-building-based usage (e.g., cultivation, plantation, or aquaculture).</td><td>A1</td><td>F</td></tr>
<tr><td>A2</td><td>VG</td></tr>
<tr><td>A3</td><td>VP</td></tr>
<tr><td>A4</td><td>VG</td></tr>
<tr><td rowspan="3">Convenience in transferring land (B)
▪ According to BAL 1960 Article 34, HGB land can be transferred to Indonesian individuals and legal entities through the entire mechanisms. In inheritance, an individual needs a will (Indonesian: Surat Wasiat) or certificate of inheritance (Surat Keterangan Waris). For other mechanisms, an Authentic Deed issued by Land Titles Registrar (PPAT) is needed.
▪ Foreigners cannot have HGB over land in Indonesia. A joint company built and reside in Indonesia can occupy land through HGB (BAL Article 36).</td><td>B1</td><td>VG</td></tr>
<tr><td>B2</td><td>VG</td></tr>
<tr><td>B3</td><td>P</td></tr>
<tr><td rowspan="3">Duration (C)
▪ HGB is a type of land rights that has a duration of occupation. The initial period of possession is limited to a maximum of 30 years. After that, you can extend your HGB landholding for a maximum of 20 years, plus an additional 30 years for renewal. The total duration of HGB is 80 years. Although HGB can deliver a period of possession for both short- and long-term possession, in practice this tenure form is more applicable to a long period of possession.</td><td>C1</td><td>P</td></tr>
<tr><td>C2</td><td>VG</td></tr>
<tr><td>C3</td><td>G</td></tr>
<tr><td rowspan="3">Accessibility and opportunity (D)
▪ According to Article 4 of Law No. 4 of 1996 concerning Mortgage Rights on Land and Objects Related to Land, HGB on state land can apply as collateral. Both the government and private banks receive HGB landholding in a mortgage. This situation shows that the land with certificates of HGB could deliver optimal access and opportunity to loan for its holder. Ginting (2017) calculated that the loan given for an HGB and HP land could reach 80% of the assessed value, only less than Hak Milik (freehold right) in the range of 90-100%.
▪ In the open land market, the market value of certificated land is typically higher than that of uncertified land, leading to a higher transaction price. High market value would lead to a higher bargaining position in the compensation delivery of a land procurement in a development project.
▪ Those who occupy land by HP are relatively easier to get support from the government because the status of the land (subject, object, and legal relationship) is legally clear.</td><td>D1</td><td>VG</td></tr>
<tr><td>D2</td><td>VG</td></tr>
<tr><td>D3</td><td>VG</td></tr>
<tr><td rowspan="3">Recognition (E)
▪ The occupation does not affect individuals who reside on HGB land to obtain a KTP/residence card. Land certificate, including HGB certificate, is the highest level of formal proof of possession according to Indonesian land administration system (Santoso, 2010).
▪ The certificate shows the formal juridical recognition from the authorities.
▪ Usually, once the neighbours understand that the authority has legally acknowledged the piece of land, they would respect the legal power embedded with the title. Therefore, HGB landholding can confer a high level of legitimacy to the land.</td><td>E1</td><td>VG</td></tr>
<tr><td>E2</td><td>VG</td></tr>
<tr><td>E3</td><td>VG</td></tr>
</table>

Security (F) ▪ In case of forced eviction and land grabbing, the formal proof of possession offers more protection, not only in civil law but also in criminal law, as the landholding is registered in the existing legal system. ▪ Because in the process of the rights assignation, a cadastral survey is officially required (not just a field check) to determine the boundary, the risk of having an incorrect position, shape, and size of the parcel can be minimized. The result of the boundary survey and detailed situation around the land is presented in a standard "Gambar Ukur," or survey chart, and then a registration map, which can prevent misinterpretation about the location. This spatial clarity helps decrease potential land disputes.	F1 F2	VG VG

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The right of use or Hak Pakai (HP)

Characteristics and descriptions	Evaluation	
Convenience in using land (A) ▪ According to BAL 1960 Article 41, HP gives the landholder a right to use and collect the land's products. The term "use" refers to the understanding that HP delivers a right to use the land primarily for building-based usage (e.g., housing, commercial, offices, services), while the term "collecting results" points to the understanding that HP can be used for other and derivative usage (Harsono, 2008). As a result, HP is a type of usufruct rights that apply for broader and more various usage, as instances for a port complex (which does not only contain buildings, but also the open areas for the vessel parking), military facilities, social and governmental facilities, beach towers, energy or power plants, or even for fish breeding occupation.	A1 A2 A3 A4	VG VG VG VG
Convenience in transferring land (B) ▪ Just like HGB, HP can be transferred to other Indonesian citizens through the entire mechanism. ▪ As regulated in Article 2 of the Government Regulation No. 103 of 2015 concerning Housing or Residential Houses by Foreigners Domiciled in Indonesia, foreign nationals are permitted to occupy property in Indonesia using HP, which indicates that the property sale between Indonesians and foreigners is accommodated by HP. In Minister of ATR/Head of BPN Regulation No. 29 of 2016 on Procedures for Assignation, Releasing, or Transferring Rights of Houses of Residential Places for Foreign Officials in Indonesia, the type of properties that could be held using HP by foreign nationals are limited to a single house (i.e., a house with no shared wall with other houses) and an apartment unit.	B1 B2 B3	VG VG VG
Duration (C) ▪ Article 45 of the Government Regulation No. 40 of 1996 (foolowed by Government Regulation No. 18 of 2021) says that HP is a land right with the duration of the occupation. For private affairs, HP on the state land is granted for 25 years maximum. The extension of the right is 20 years and the renewal is 20 years. In total, HP can be assigned for 70 years to a single entity (individuals or legal bodies). ▪ Although both HGB and HP provide a quite long duration, in practice HGB is frequently used for long-term occupation, whereas HP is more flexible for shorter-term occupation following the duration of the land use.	C1 C2 C3	F VG VG

▪ The rule of the duration does not apply for governmental agencies, international bodies, and social and religious bodies (HP for Public Affairs). These entities can use the HP land as long as needed.		
Accessibility and opportunity (D) ▪ The explanation is the same as the HGB's, except that the HP land for governmental, international agencies, and social and religious bodies affairs (i.e., HP for Public Affairs) cannot be submitted as collateral for a loan.	D1	G
	D2	VG
	D3	VG
Recognition (E) ▪ About Recognition, the explanation of HP is the same as the HGB's.	E1	VG
	E2	VG
	E3	VG
Security (F) ▪ About Security, the explanation of HP is the same as the HGB's.	F1	VG
	F2	VG

***

Communal rights or Hak Komunal (HK)

Characteristics and descriptions	Evaluation	
Convenience in using land (A) ▪ HK can facilitate any use of communal land agreed upon by the indigenous groups or the community. HK can be assigned to secure tenure of community residential, fish catching and breeding, or cultural heritage area. ▪ Because HK is about communal possession, not individual-based possession, it is not completely relevant for commercial and business places, which demand individual use.	A1	G
	A2	VG
	A3	VG
	A4	P
Convenience in transferring land (B) ▪ According to Minister of ATR/BPN Regulation No. 10 of 2016 concerning Procedures for the Establishment of Communal Rights on Indigenous People's Land and Communities Under Specific Areas, HK can be divided into two types: HK for indigenous lands and HK for communities in certain areas. There are only four legal subjects that can obtain HK, namely (1) All members of a customary group (as a whole), (2) Customary leaders on behalf of customary law communities, (3) Community groups living in certain areas (forest or plantation areas) or their representatives, and (4) Cooperative management. ▪ The foreign nationals or foreign legal bodies cannot be the subject of HK. ▪ HK cannot be given to an individual. ▪ The land transfer is only possible with inheritance and exchange. In the indigenous community, the transfer procedures are following the norms and customs that apply, whereas, in community lands, if the transfer through sale or exchange wants to be conducted, the transfer should take the whole area, and therefore the process needs a release of right (Indonesian: pelepasan hak) from the leaders and agreement by all members of the community or representatives. A company cannot auction HK for community lands and use them as capital.	B1	P
	B2	P
	B3	VP
Duration (C) ▪ There are no restrictions regarding the duration of possession. In other words, HK does not have a holding time limit. Because HK is often described as the formalization of customary rights and whose idea is about protecting	C1	VG
	C2	G
	C3	P

the existence of group land (Rachman, 2016), we can assume that the original intention of HK assignment is placing the right to the land as long as possible.		
Accessibility and opportunity (D) ▪ HK cannot be used as collateral to the bank. ▪ However, just like HGB and HP, with legal clarity regarding the subject, object, and the relations of those in a certificate as a formal document, HK opens high opportunities to get the government supports in the area. The same situation holds true for development projects, where the government would respectfully provide compensation in accordance with the certificate.	D1	VP
	D2	VG
	D3	VG
Recognition (E) ▪ People living in the HK land are eligible to obtain a KTP/residence card without any obstruction. ▪ The same with HGB and HP, the assignation of HK implies legal and formal recognition from the government regarding the existence of rights held by the people. ▪ Because of its communal nature, HK's recognition is high among surrounding landholders.	E1	VG
	E2	VG
	E3	VG
Security (F) ▪ The explanation of the security setting of HK is, in general, the same as the HGB's. No different from HGB and HP, administratively HK provides the same situation as the most reliable guarantee of legal protection from possible land encroachment. In practice, HK offers more protection because it is not a land right for an individual, so all community members or their representatives must approve any acquisition. A significant added value of HK is its collective power. HK is also a forceful right in the sense that it is a type of possession right that is already at the level of ownership. We can refer to HK as a collective freehold right.	F1	VG
	F2	VG

***

Tenure by Sewa Kontrak (SWK) system

Characteristics and descriptions	**Evaluation**	
Convenience in using land (A) ▪ The contract between the proprietor and the tenant completely confines the use of the property through the SWK system to the prior agreement. It is not as free as SKT for example, which gives the landholder the ability to use the land for any needs without permission from the other party. In Tanjungpinang, the utilization of SWK land is generally in the form of houses, shops, and shop-houses (Indonesian: ruko, which is a multi-storey building combined by upper floors for houses and the ground floor for shops).	A1	G
	A2	VG
	A3	F
	A4	VG
Convenience in transferring land (B) ▪ Inheritance, auctions, grants, exchanges, or incorporation into a company's capital cannot transfer SWK land. However, the property can be leased again by the lessee to the third party with the proprietor's consent. ▪ A foreign national cannot formally lease a property through SWK system.	B1	VP
	B2	P
	B3	VP
Duration (C) ▪ The duration of property holding depends on the contract. Typically in Tanjungpinang coastline settlements, the initial lease period is at least one	C1	VP
	C2	F
	C3	G

year (12 months) and can be extended as agreed. Therefore, SWK system is supposed to apply for short-term occupation.		
Accessibility and opportunity (D) ▪ Because its tenure period is short, the contract cannot be submitted as collateral for a loan. ▪ The opportunity to get any assistance, for example, house renovation, is not as big as a certificated land or SKT land. ▪ As seen in Kampung Bugis Village, the government is more likely to prioritize the land by SKT than by SWK system. The same situation also applies regarding compensation in a land procurement project.	D1 D2 D3	VP VP VP
Recognition (E) ▪ The tenure is stated in an authentic deed called Deed of a Leasing Agreement (Indonesian: Akta Perjanjian Sewa Menyewa) from a public notary. The deed applies as formal proof of possession and also proof of recognition from the aspect of public administration. Although this kind of proof is not as high as certificates that are issued by the authoritative bodies in land administration sector, the deed is a formal, legal, and therefore legitimate document. ▪ The tenants are eligible to obtain a KTP/residence card using their tenancy address as the place of residence. Although not as high as the certificates', the SWK possession is acknowledged by the neighbours. Usually, with the condition that the new occupant reports its contract to the head of RT and RW.	E1 E2 E3	G G G
Security (F) ▪ The deed is a formal and legit product. It makes the land controlled under the SWK system have legal strength to prevent it from easily being seized and expelled. However, because the power of possession by the tenant is given by the proprietor and not directly by the authorities as in the certificates, the legal securing power of the deed is considered lower than the certificates in the case of external disturbance (e.g., land grabbing). ▪ In the case of internal disputes (between the tenant and the proprietor), the formal contract delivers better protection compared to the agreement without a contract.	F1 F2	G G

***

Location Permit (Izin Lokasi/IL and Management Permit (Izin Pengelolaan/IP), then so-called IL/IP

Characteristics and descriptions	Evaluation	
Convenience in using land (A) According to Article 16 of Law No. 1 of 2014 concerning the Management of Coastal Areas and Small Islands, and subsequently Permen KP No. 10 of 2024 regarding the utilization of small islands and their surrounding waters, the tenure system regulates the use of these areas up to 12 nautical miles from the shoreline. IL/IP regulates any activities in the sector of salt production, marine biopharmacology, marine biotechnology, marine tourism, marine cultivation, utilization of seawater apart from energy, installation of submarine pipes and cables, and removal of sinking cargo objects. In Article 35 of Government Regulation Draft concerning local and traditional communities, IL/IP system regulates salt production, marine tourism, and fishing activities. Following the	A1 A2 A3 A4	F G VG F

Law No 6/2023 on Job Creation, transportation sectors, oil and gas, mineral and mining, building constructions, telecommunication are also included. From this scope of operations, we can conclude that part of IL/IP activities are compatible with land use in coastline settlement areas. However, IL/IP, in the form of KKPR, this tenure is still applicable for residential, commercial and service-based utilization (resort, hotel, restaurant, swift bird nest, harbour areas), and some aquaculture activities around the coastline settlement (i.e., fishing breeding karamba, and fish capturing bagan, seaweed cultivation).		
Convenience in transferring land (B) The land owned by IL/IP cannot be sold, inherited, auctioned, made into grants, exchanged, or included in the capital of a company, either to Indonesians or foreign nationals.	B1 B2 B3	VP VP VP
Duration (C) IL/IP enforces a duration of tenure, which can be divided based on the subject and type of the permit: **To individuals, corporations, and cooperatives, the maximum validity of IL/IP** ▪ Salt production, marine biopharmacology, and marine biotechnology: 5 years. ▪ Marine tourism: 20 years ▪ Utilization of seawater other than energy: 10 years ▪ Installation of submarine pipes and cables: 30 years ▪ Removal of sinking cargo objects: 2 years If the permit ends, the new assessment is required to obtain a new permit. **To the local and traditional community:** To all types of land usage, the period of IL/IP is two years and can be extended twice. So, in total, IL/IP could be six years. After six years, if the activity is still ongoing, there must be a new permit application that requires a new assessment from the authorities. K**KPR** In the form of KKPR, it can be considered a "pre-permit" or a "basic requirement" that acts as a fundamental prerequisite for subsequent business licenses in Indonesia. KKPR is valid for 2 years. If then there is a business license during this 2 year period, KKPR will follow the validity period of the business license, which can be up to 20 years.	C1 C2 C3	VP F VG
Accessibility and opportunity (D) ▪ IL/IP holders cannot submit the permit to the bank for collateral. ▪ The chance to get infrastructure support from the government is not impeded. Even for the activities related to fishery business, such as the development of jetties or sedimentary dredging for boat lines, the IL/IP area can be prioritized. ▪ The economic valuation of the area guides the fairness of compensation in land acquisition for fisheries. However, in the valuation process, IL/IP permit as a legal status variable is weighted not as big as land certificates.	D1 D2 D3	VP F F
Recognition (E) ▪ The provision of IL/IP from the authorities indicates an administration and formal recognition from the state. The length of time is written on a letter	E1 E2 E3	G G G

called "Surat Keterangan Pemanfaatan Sumber Daya Pesisir dan Pulau-pulau Kecil," which means "Letter of Coastal and Small Island Resource Use". ▪ Land Technical Review (*Pertimbangan Teknis Pertanahan*) form Land Office is required. For some cases, a letter of clearance from the related stakeholders (e.g., local government), and a consent document from the locals are required in the application process. It indicates that the recognition from the surroundings is also considered.		
Security (F) ▪ Although its legal security degree is considered lower than the certificates, the formal provision of IL/IP permit from the government gives an administrative backup and clarity of the activities in the coastal areas. ▪ The boundary of the permit, which is also surveyed and presented in a standardized map (not just in an unscaled drawing as in most of the informal tenure forms), prevents unclear occupation areas. This spatial clarity helps to prevent boundary disputes.	F1 F2	G G

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Surat Pembudidayaan Ikan (SPI).

Characteristics and descriptions	Evaluation	
Convenience in using land (A) ▪ SPI provides its landholders with a limited breadth of usage. SPI only regulates fisheries activities (e.g., fish farm, fish breeding).	A1 A2 A3 A4	P VP VG VP
Convenience in transferring land (B) ▪ Neither Indonesian nor foreign nationals may purchase, inherit, auction, grant, exchange, or include SPI lands in their capital.	B1 B2 B3	VP VP VP
Duration (C) ▪ According to Riau Islands Province Regulation No. 6 of 2006 on Fisheries Activities in Riau Islands Province, the period of SPI is three years. One can extend the SPI for an additional three years, bringing the maximum license period to six years. If the activities continue, the letter holder can request a new permit through a new assessment. We can infer that SIPI only provides temporary possession based on this time limit.	C1 C2 C3	VP P VG
Accessibility and opportunity (D) ▪ SPI landholding cannot serve as collateral for a loan because it is a permit-based possession. ▪ The option to get support from the government is not hindered, although the focus of the supports is on the fishery sectors and common infrastructures, for example, the construction of a Fish Auction Market or boat jetties. ▪ In terms of compensation, SPI has a similar situation to IL/IP.	D1 D2 D3	VP F G
Recognition (E) ▪ About Recognition, the explanation of SPI is the same as the IL/IP's.	E1 E2 E3	G G G
Security (F) ▪ About Security, the explanation of SPI is the same as the IL/IP's.	F1	G

Appendix 5. Fuzzy TOPSIS Calculation

1. CONSTRUCTING FUZZY DECISION MATRIX

	A1			A2			A3			A4			B1, B2, B3,C1,...E3			F1			F2		
	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c
HGB	2,5	5	7,5	7,5	10	10	0	0	2,5	7,5	10	10	...	...	...	7,5	10	10	7,5	10	10
SPI	0	2,5	5	0	0	2,5	7,5	10	10	0	0	2,5	...	...	...	5	7,5	10	5	7,5	10
HP	7,5	10	10	7,5	10	10	7,5	10	10	7,5	10	10	...	...	...	7,5	10	10	7,5	10	10
HK	5	7,5	10	7,5	10	10	7,5	10	10	0	2,5	5	...	...	...	7,5	10	10	7,5	10	10
SKT	7,5	10	10	7,5	10	10	5	7,5	10	5	7,5	10	...	...	...	5	7,5	10	5	7,5	10
GR	5	7,5	10	2,5	5	7,5	2,5	5	7,5	0	0	2,5	...	...	...	0	0	2,5	0	0	2,5
ST	5	7,5	10	5	7,5	10	5	7,5	10	0	0	2,5	...	...	...	0	2,5	5	0	2,5	5
SWBT	5	7,5	10	7,5	10	10	2,5	5	7,5	5	7,5	10	...	...	...	2,5	5	7,5	2,5	5	7,5
IL/IP	2,5	5	7,5	0	0	2,5	7,5	10	10	2,5	5	7,5	...	...	...	5	7,5	10	5	7,5	10
SWK	5	7,5	10	7,5	10	10	2,5	5	7,5	7,5	10	10	...	...	...	5	7,5	10	5	7,5	10
NB	2,5	5	7,5	7,5	10	10	2,5	5	7,5	2,5	5	7,5	...	...	...	2,5	5	7,5	5	7,5	10
WEIGHTS OF SUBCRITERIA*	0,011239	0,011239	0,011239	0,01184	0,01184	0,01184	0,006503	0,006503	0,006503	0,004639	0,004639	0,004639	...	...	...	0,012497	0,012497	0,012497	0,010211	0,010211	0,010211

* From AHP

2. CONSTRUCTING THE NORMALIZED FUZZY DECISION MATRIX

	A1			A2			A3			A4			B1, B2, B3,C1,...E3			F1			F2		
	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c
HGB	0	0,5	0,75	0,75	1	1	0	0	0,25	0,75	1	1	...	...	...	0,75	1	1	0,75	1	1
SPI	0	0,25	0,5	0	0	0,25	0,75	1	1	0	0	0,25	...	...	...	0,5	0,75	1	0,5	0,75	1
HP	0,75	1	1	0,75	1	1	0,75	1	1	0,75	1	1	...	...	...	0,75	1	1	0,75	1	1
HK	0,5	0,75	1	0,75	1	1	0,75	1	1	0	0,25	0,5	...	...	...	0,75	1	1	0,75	1	1
SKT	0,75	1	1	0,75	1	1	0,5	0,75	1	0,5	0,75	1	...	...	...	0,5	0,75	1	0,5	0,75	1
GR	0,5	0,75	1	0,25	0,5	0,75	0,25	0,5	0,75	0	0	0,25	...	...	...	0	0	0,25	0	0	0,25
ST	0,5	0,75	1	0,5	0,75	1	0,5	0,75	1	0	0	0,25	...	...	...	0	0,25	0,5	0	0,25	0,5
SWBT	0,5	0,75	1	0,75	1	1	0,25	0,5	0,75	0,5	0,75	1	...	...	...	0,25	0,5	0,75	0,25	0,5	0,75
IL/IP	0,25	0,5	0,75	0	0	0,25	0,75	1	1	0,25	0,5	0,75	...	...	...	0,5	0,75	1	0,5	0,75	1
SWK	0,5	0,75	1	0,75	1	1	0,25	0,5	0,75	0,75	1	1	...	...	...	0,5	0,75	1	0,5	0,75	1
NB	0,25	0,5	0,75	0,75	1	1	0,25	0,5	0,75	0,25	0,5	0,75	...	...	...	0,25	0,5	0,75	0,5	0,75	1

c max = 10

3. CONSTRUCTING THE FUZZY WEIGHTED NORMALIZED DECISION MATRIX

	A1			A2			A3			A4			B1, B2, B3,C1,...E3			F1			F2		
	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c
HGB	0	0,00562	0,00843	0,00888	0,01184	0,01184	0	0	0,001626	0,003479	0,004639	0,004639	...	...	...	0,009373	0,012497	0,012497	0,007659	0,010211	0,010211
SPI	0	0,00281	0,00562	0	0	0,00296	0,004877	0,006503	0,006503	0	0	0,00116	...	...	...	0,006249	0,009373	0,012497	0,005106	0,007659	0,010211
HP	0,00843	0,011239	0,011239	0,00888	0,01184	0,01184	0,004877	0,006503	0,006503	0,003479	0,004639	0,004639	...	...	...	0,009373	0,012497	0,012497	0,007659	0,010211	0,010211
HK	0,00562	0,00843	0,011239	0,00888	0,01184	0,01184	0,004877	0,006503	0,006503	0	0,00116	0,00232	...	...	...	0,009373	0,012497	0,012497	0,007659	0,010211	0,010211
SKT	0,00843	0,011239	0,011239	0,00888	0,01184	0,01184	0,003251	0,004877	0,006503	0,00232	0,003479	0,004639	...	...	...	0,006249	0,009373	0,012497	0,005106	0,007659	0,010211
GR	0,00562	0,00843	0,011239	0,00296	0,00592	0,00888	0,001626	0,003251	0,004877	0	0	0,00116	...	...	...	0	0	0,003124	0	0	0,002553
ST	0,00562	0,00843	0,011239	0,00592	0,00888	0,01184	0,003251	0,004877	0,006503	0	0	0,00116	...	...	...	0	0,003124	0,006249	0	0,002553	0,005106
SWBT	0,00562	0,00843	0,011239	0,00888	0,01184	0,01184	0,001626	0,003251	0,004877	0,00232	0,003479	0,004639	...	...	...	0,003124	0,006249	0,009373	0,002553	0,005106	0,007659
IL/IP	0,00281	0,00562	0,00843	0	0	0,00296	0,004877	0,006503	0,006503	0,00116	0,00232	0,003479	...	...	...	0,006249	0,009373	0,012497	0,005106	0,007659	0,010211
SWK	0,00562	0,00843	0,011239	0,00888	0,01184	0,01184	0,001626	0,003251	0,004877	0,003479	0,004639	0,004639	...	...	...	0,006249	0,009373	0,012497	0,005106	0,007659	0,010211
NB	0,00281	0,00562	0,00843	0,00888	0,01184	0,01184	0,001626	0,003251	0,004877	0,00116	0,00232	0,003479	...	...	...	0,003124	0,006249	0,009373	0,005106	0,007659	0,010211

4 DETERMINE FPI **With regards to the elements**

are normalized positive triangular fuzzy numbers and their ranges belong to the closed interval [0; 1] so the FPIS and FNIS will be

FPIS (A+)																					
fuzzy positive id	the highest value	1	1	1	1	1	1	1	1	1	1	1	1	...	...	...	1	1	1	1	1	1
FNIS (A-)																					
fuzzy negative id	the lowest value	0	0	0	0	0	0	0	0	0	0	0	0	...	...	...	0	0	0	0	0	0

5. DISTANCE OF EACH ALTERNATIVE FROM A+ WITH RESPECT TO EACH CRITERIA

	A1	A2	A3	A4	B1, B2, B3,C1,...E3	F1	F2	D+	
d (A HGB, A+)	0,995323	0,989148	0,999458	0,995748	...	0,988545	0,99064	17,87203	d (A HGB, A-)
d (A SIPI, A+)	0,997193	0,999014	0,994039	0,999614	...	0,99063	0,992344	17,92621	d (A SIPI, A-)
d (A HP, A+)	0,989698	0,989148	0,994039	0,995748	...	0,988545	0,99064	17,85671	d (A HP, A-)
d (A HK, A+)	0,991573	0,989148	0,994039	0,998841	...	0,988545	0,99064	17,87601	d (A HK, A-)
d (A SKT, A+)	0,989698	0,989148	0,995124	0,996521	...	0,99063	0,992344	17,87483	d (A SKT, A-)
d (A GR, A+)	0,991573	0,994083	0,996749	0,999614	...	0,99896	0,99915	17,95114	d (A GR, A-)
d (A ST, A+)	0,991573	0,991123	0,995124	0,999614	...	0,996879	0,997449	17,92448	d (A ST, A-)
d (A SWBT, A+)	0,991573	0,989148	0,996749	0,996521	...	0,993755	0,994896	17,93863	d (A SWBT, A-)
d (A IL/IP, A+)	0,994383	0,999014	0,994039	0,997681	...	0,99063	0,992344	17,91989	d (A IL/IP, A-)
d (A SWK, A+)	0,991573	0,989148	0,996749	0,995748	...	0,99063	0,992344	17,9183	d (A SWK, A-)
d (A NB, A+)	0,994383	0,989148	0,996749	0,997681	...	0,993755	0,992344	17,89956	d (A NB, A-)

6. DISTANCE OF EACH ALTERNATIVE FROM A- WITH RESPECT TO EACH CRITERIA

	A1	A2	A3	A4	B1, B2, B3,C1,...E3	F1	F2	D-	
d (A HGB, A-)	0,005849	0,010943	0,000939	0,004288	...	0,01155	0,009438	0,131764	d (A HGB, A-)
d (A SIPI, A-)	0,003628	0,001709	0,00601	0,00067	...	0,009714	0,007937	0,081016	d (A SIPI, A-)
d (A HP, A-)	0,010388	0,010943	0,00601	0,004288	...	0,01155	0,009438	0,145145	d (A HP, A-)
d (A HK, A-)	0,008736	0,010943	0,00601	0,001497	...	0,01155	0,009438	0,127369	d (A HK, A-)
d (A SKT, A-)	0,010388	0,010943	0,005055	0,003606	...	0,009714	0,007937	0,128755	d (A SKT, A-)
d (A GR, A-)	0,008736	0,006394	0,003512	0,00067	...	0,001804	0,001474	0,057928	d (A GR, A-)
d (A ST, A-)	0,008736	0,009203	0,005055	0,00067	...	0,004034	0,003296	0,083459	d (A ST, A-)
d (A SWBT, A-)	0,008736	0,010943	0,003512	0,003606	...	0,006749	0,005515	0,068973	d (A SWBT, A-)
d (A IL/IP, A-)	0,00607	0,001709	0,00601	0,002505	...	0,009714	0,007937	0,086667	d (A IL/IP, A-)
d (A SWK, A-)	0,008736	0,010943	0,003512	0,004288	...	0,009714	0,007937	0,088242	d (A SWK, A-)
d (A NB, A-)	0,00607	0,010943	0,003512	0,002505	...	0,006749	0,007937	0,105557	d (A NB, A-)

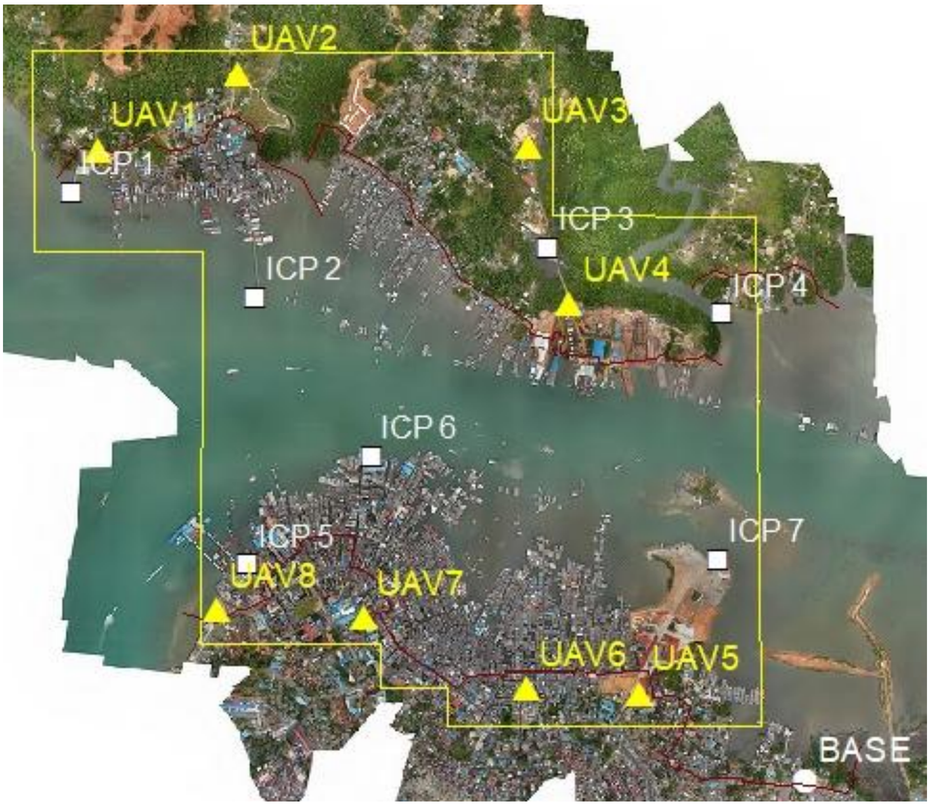
7 CALCULATING CLOSENESS COEFFICIENT (CC)

CC GHB	0,007319
CC SPI	0,004499
CC HP	0,008063
CC HK	0,007075
CC SKT	0,007152
CC GR	0,003217
CC ST	0,004635
CC SWBT	0,00383
CC Il/IP	0,004813
CC SWK	0,004901
CC NB	0,005863

8. RANKING OF EVERY ALTERNATIVE

	CC		Ranking	Dj+	Dj-
HP	0,008063		1	17,85671	0,145145
HGB	0,007319		2	17,87203	0,131764
SKT	0,007152		3	17,87483	0,128755
HK	0,007075		4	17,87601	0,127369
NB	0,005863		5	17,89956	0,105557
SWK	0,004901		6	17,9183	0,088242
IL/IP	0,004813		7	17,91989	0,086667
ST	0,004635		8	17,92448	0,083459
SPI	0,004499		9	17,92621	0,081016
SWBT	0,00383		10	17,93863	0,068973
GR	0,003217		11	17,95114	0,057928

Appendix 6. GCPs and ICPs



GCP

Easting	Northing	ELEV		LATITUDE	LONGITUDE	LABEL	Status
437217,713	104346,527	1,7379	1,998	0° 56' 38.4318" N	104° 26' 08.6083" E	UAV1	Rover 2
437704,526	104612,327	3,8604	4,118	0° 56' 47.0911" N	104° 26' 24.3578" E	UAV2	Base 2
438707,311	104360,682	3,9799	4,234	0° 56' 38.9005" N	104° 26' 56.8044" E	UAV3	Base 1
438850,753	103813,167	1,9113	2,167	0° 56' 21.0694" N	104° 27' 01.4483" E	UAV4	Rover 1
439090,461	102467,543	2,8031	3,065	0° 55' 37.2454" N	104° 27' 09.2108" E	UAV5	Rover 4
438702,942	102486,468	2,1261	2,389	0° 55' 37.8598" N	104° 26' 56.6725" E	UAV6	Base 4
438140,407	102728,929	4,6003	4,864	0° 55' 45.7535" N	104° 26' 38.4705" E	UAV7	Rover 3
437632,249	102757,273	2,273	2,538	0° 55' 46.6741" N	104° 26' 22.0289" E	UAV8	Base 3

Example of a GCP measurement (UAV 3) using static solution, and UAV 4 using rapid static (fixed solution)

Trimble

Post-Processing Service Based on RTX Technology

TrimbleRTX.com

Contributor:	kuncoro.fabrian@gmail.com
Reference Name:	09750630.T02
Upload Date:	03/06/2017 11:41:41 UTC
Report Time Frame:	
Start Time:	03/04/2017 03:36:46 UTC
End Time:	03/04/2017 05:01:24 UTC
Observation File Type(s):	T02
Observation File(s):	09750630.T02
Antenna:	
Name:	TRM55970.00 NONE
Height:	2.000 m
Reference:	Bottom of antenna mount
Receiver Name:	TRIMBLE NETR9
Coordinate Systems:	ITRF2008
Tectonic Plate:	Eurasia
Tectonic Plate Model:	MORVEL56
Processing Interval:	10 s

Statistics

# Total Obs	# Usable Obs	# Used Obs	Percent
2540	508	501	98

Used Satellites

# Total Satellites:	18
GPS:	G10 G14 G16 G18 G21 G25 G26 G27 G29 G31 G32
GLONASS:	R01 R07 R08 R10 R11 R13 R22

Processing Results

ITRF2008 at Epoch 2005.0		
Coordinate	Value	σ
X	-1591261.819 m	0.007 m
Y	6175575.598 m	0.017 m
Z	104393.206 m	0.005 m
Latitude	00° 56' 38.90389" N	0.005 m
Longitude	104° 26' 56.79693" E	0.007 m
El. Height	14.733 m	0.017 m

ITRF2008 at Epoch 2017.17		
Coordinate	Value	σ
X	-1591262.042 m	0.007 m
Y	6175575.542 m	0.017 m
Z	104393.104 m	0.005 m
Latitude	00° 56' 38.90056" N	0.005 m
Longitude	104° 26' 56.80438" E	0.007 m
El. Height	14.733 m	0.017 m

Report Information

Trimble RTX Solution ID:	8230343
Solution Type:	Static
Software Version:	5.0.0.15127
Creation Date:	03/06/2017 11:42:23 UTC

UAV 3 report

Project information		Coordinate System	
Name:		Name:	Indonesia
Size:		Datum:	ITRF
Modified:		Zone:	48.1
Time zone:		Geoid:	EGM96 (Global)
Reference number:		Vertical datum:	
Description:			

Baseline Processing Report

Processing Summary

Observation	From	To	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
uav 3 --- uav 4 (B1)	uav 3	uav 4	Fixed	0,003	0,004	165°18'37"	566,194	-2,056

Acceptance Summary

Processed	Passed	Flag	Fail
1	1	0	0

uav 3 - uav 4 (10:57:48-11:57:48) (S1)

Baseline observation:	uav 3 --- uav 4 (B1)
Processed:	06/03/2017 18:00:42
Solution type:	Fixed
Frequency used:	Dual Frequency (L1, L2)
Horizontal precision:	0,003 m
Vertical precision:	0,004 m
RMS:	0,000 m
Maximum PDOP:	1,727
Ephemeris used:	Broadcast
Antenna model:	NGS Relative
Processing start time:	04/03/2017 10:57:48 (Local: UTC+7hr)
Processing stop time:	04/03/2017 11:57:48 (Local: UTC+7hr)
Processing duration:	01:00:00
Processing interval:	2 seconds

UAV 3 (base) to UAV 4 (rover) report

ICP

Label	ICP coordinate (GNSS survey)		
	Easting (m)	Northing (m)	Elev (m)
Base	439666.329	102165.995	1,672
ICP 1	437129.229	104201.161	2,619
ICP 2	437765.197	103837.827	3,597
ICP 3	438777.793	104011.251	1,277
ICP 4	439378.635	103780.609	2,965
ICP 5	437739.464	102915.231	2,736
ICP 6	438165.95	103287.847	2,306
ICP 7	439364.408	102933.275	1,495

Base for ICP

Trimble

Post-Processing Service Based on RTX Technology

TrimbleRTX.com

Contributor:	kuncoro.fabrian@gmail.com
Reference Name:	09751540.T02
Upload Date:	06/05/2017 02:48:32 UTC
Report Time Frame:	
Start Time:	06/03/2017 03:35:40 UTC
End Time:	06/03/2017 12:07:26 UTC
Observation File Type(s):	T02
Observation File(s):	09751540.T02
Antenna:	
Name:	TRM55970.00 NONE
Height:	2.000 m
Reference:	Bottom of antenna mount
Receiver Name:	TRIMBLE NETR9
Coordinate Systems:	ITRF2008 & ITRF2014
Tectonic Plate:	Eurasia
Tectonic Plate Model:	MORVEL56
Processing Interval:	10 s

Statistics

# Total Obs	# Usable Obs	# Used Obs	Percent
15354	3070	3070	100

Used Satellites

# Total Satellites:	35
GPS:	G01 G02 G03 G05 G06 G07 G08 G09 G11 G12 G13 G17 G19 G20 G22 G23 G27 G28 G30 G31
GLONASS:	R01 R05 R06 R07 R08 R09 R10 R11 R13 R16 R18 R19 R20 R21 R22

Processing Results

ITRF2008 at Epoch 2005.0		
Coordinate	Value	σ
X	-1592199.449 m	0.005 m
Y	6175368.305 m	0.011 m
Z	102198.142 m	0.003 m
Latitude	00° 55' 27.43069" N	0.003 m
Longitude	104° 27' 27.83686" E	0.005 m
El. Height	12.233 m	0.011 m

ITRF2014 at Epoch 2017.42		
Coordinate	Value	σ
X	-1592199.679 m	0.005 m
Y	6175368.247 m	0.011 m
Z	102198.035 m	0.003 m
Latitude	00° 55' 27.42720" N	0.003 m
Longitude	104° 27' 27.84452" E	0.005 m
El. Height	12.232 m	0.011 m

Report Information

Trimble RTX Solution ID:	9892197
Solution Type:	Static
Software Version:	6.1.3.17124
Creation Date:	06/05/2017 02:50:07 UTC

Rover for ICP

Project information		Coordinate System	
Name:		Name:	UTM
Size:		Datum:	WGS 1984
Modified:		Zone:	48 North (105E)
Time zone:		Geoid:	EGM96 (Global)
Reference number:		Vertical datum:	
Description:			

Baseline Processing Report

Processing Summary

Observation	From	To	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
Base --- icp1 (B1)	Base	icp1	Fixed	0,007	0,009	308°43'35"	3253,651	0,822
Base --- icp2 (B2)	Base	icp2	Fixed	0,037	0,069	311°19'09"	2532,559	1,830
Base --- icp3 (B3)	Base	icp3	Fixed	0,007	0,012	334°16'45"	2048,765	-0,450
Base --- icp4 (B4)	Base	icp4	Fixed	0,050	0,087	349°53'17"	1640,627	1,265
Base --- icp5 (B5)	Base	icp5	Fixed	0,004	0,008	69°00'39"	789,004	0,924
Base --- icp6 (B6)	Base	icp6	Fixed	0,016	0,025	291°14'21"	2068,136	0,976
Base --- icp7 (B7)	Base	icp7	Fixed	0,030	0,218	306°46'38"	1874,080	0,561
Base --- icp8 (B8)	Base	icp8	Fixed	0,004	0,008	338°30'43"	824,837	-0,197

Acceptance Summary

Processed	Passed	Flag	Fail
8	7	0	1

Appendix 7. The orthophoto generation report

Tanjungpinang project

Processing Report
03 April 2017

Survey Data

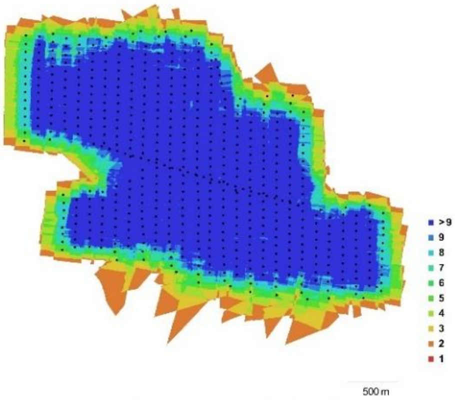


Fig. 1. Camera locations and image overlap.

Number of images:	642	Camera stations:	606
Flying altitude:	342 m	Tie points:	1,437,184
Ground resolution:	8.59 cm/pix	Projections:	4,406,440
Coverage area:	8.48 km²	Reprojection error:	1.37 pix

Camera Model	Resolution	Focal Length	Pixel Size	Precalibrated
DSC-QX10 (4.45 mm)	4896 x 3672	4.45 mm	unknown	No
DSC-QX10 (4.45 mm)	3672 x 4896	4.45 mm	unknown	No

Table 1. Cameras.

Camera Calibration

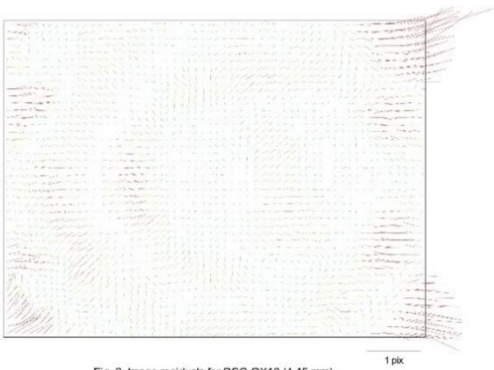


Fig. 2. Image residuals for DSC-QX10 (4.45 mm).

DSC-QX10 (4.45 mm)
548 images

Resolution	Focal Length	Pixel Size	Precalibrated
4896 x 3672	**4.45 mm**	**unknown**	**No**

Type:	Frame	F:	3622.06
Cx:	63.258	B1:	-0.220903
Cy:	19.5075	B2:	-0.0683003
K1:	-0.000121288	P1:	0.00482423
K2:	-0.0210943	P2:	0.00286713
K3:	0.017579	P3:	0
K4:	0	P4:	0

Camera Calibration

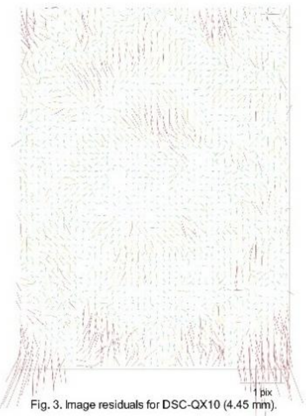


Fig. 3. Image residuals for DSC-QX10 (4.45 mm).

DSC-QX10 (4.45 mm)
94 images

Resolution	Focal Length	Pixel Size	Precalibrated
3672 x 4896	**4.45 mm**	**unknown**	**No**

Type:	Frame	F:	3622.33
Cx:	-16.867	B1:	0.281681
Cy:	69.1619	B2:	0.180185
K1:	0.000414791	P1:	-0.00280434
K2:	-0.0235094	P2:	0.00503803
K3:	0.0209213	P3:	0
K4:	0	P4:	0

Camera Locations

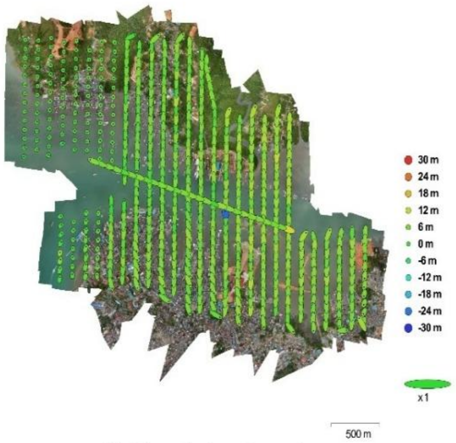


Fig. 4. Camera locations and error estimates.
Z error is represented by ellipse color. X,Y errors are represented by ellipse shape.
Estimated camera locations are marked with a black dot.

X error (m)	Y error (m)	Z error (m)	XY error (m)	Total error (m)
19.7316	69.5898	6.03284	72.3331	72.5843

Table 2. Average camera location error.

Ground Control Points

Fig. 5. GCP locations.

Count	X error (cm)	Y error (cm)	Z error (cm)	XY error (cm)	Total (cm)	Image (pix)
8	1.24993	0.898259	0.51031	1.53922	1.62161	0.590

Table 3. Control points RMSE.

Label	X error (cm)	Y error (cm)	Z error (cm)	Total (cm)	Image (pix)
UAV1	-0.716179	0.487964	0.0959733	0.871912	0.353 (12)
UAV2	0.866289	-1.49592	0.500432	1.79963	0.559 (10)
UAV3	0.652474	1.43441	-0.471663	1.64491	0.714 (16)
UAV4	-0.751736	-1.13223	0.745222	1.54997	0.578 (7)
UAV5	-0.00957365	-0.132543	0.14754	0.198563	0.435 (11)
UAV6	1.36862	0.746497	-0.153687	1.56653	0.321 (10)
UAV7	-2.7095	-0.220224	0.979563	2.88954	0.766 (9)
UAV8	1.0148	0.127469	-0.202312	1.04259	0.780 (10)
Total	**1.24993**	**0.898259**	**0.51031**	**1.62161**	**0.590**

Table 4. Control points.

Digital Elevation Model

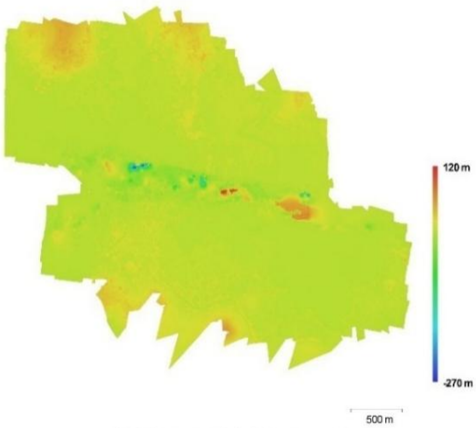


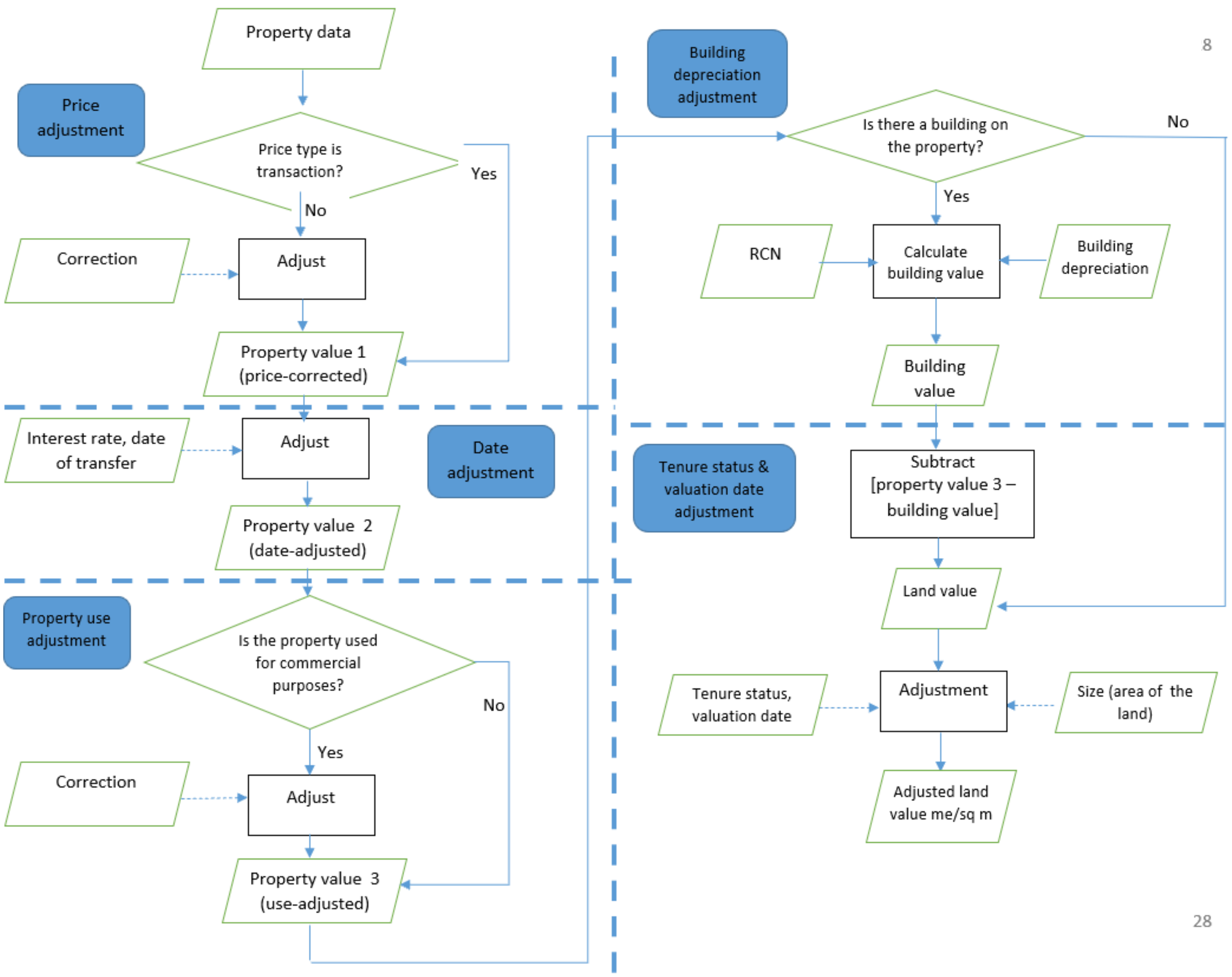
Fig. 6. Reconstructed digital elevation model.

Resolution:	34.4 cm/pix
Point density:	8.47 points/m²

Processing Parameters

General	
Cameras	642
Aligned cameras	606
Markers	8
Coordinate system	WGS 84 (EPSG::4326)
Point Cloud	
Points	1,437,184 of 1,567,072
RMS reprojection error	0.195681 (1.36686 pix)
Max reprojection error	1.268 (53.5853 pix)
Mean key point size	6.23065 pix
Effective overlap	3.21148
Alignment parameters	
Accuracy	High
Pair preselection	Generic
Key point limit	700,000
Tie point limit	700,000
Constrain features by mask	No
Adaptive camera model fitting	Yes
Matching time	2 hours 40 minutes
Alignment time	2 hours 15 minutes
Optimization parameters	
Parameters	f, b1, b2, cx, cy, k1-k3, p1, p2
Optimization time	7 minutes 45 seconds
Dense Point Cloud	
Points	73,414,510
Reconstruction parameters	
Quality	Medium
Depth filtering	Aggressive
Depth maps generation time	2 hours 43 minutes
Dense cloud generation time	39 minutes 18 seconds
Model	
Faces	14,682,669
Vertices	7,341,451
Texture	4,096 x 4,096, uint8
Reconstruction parameters	
Surface type	Height field
Source data	Dense
Interpolation	Extrapolated
Quality	Medium
Depth filtering	Aggressive
Face count	14,682,902
Processing time	8 minutes 18 seconds
Texturing parameters	
Mapping mode	Orthophoto
Blending mode	Mosaic
Texture size	4,096 x 4,096
Enable color correction	No
Enable hole filling	Yes
UV mapping time	3 minutes 5 seconds
Blending time	7 minutes 54 seconds
DEM	
Size	17,972 x 17,696
Coordinate system	WGS 84 (EPSG::4326)
Reconstruction parameters	
Source data	Dense cloud
Interpolation	Enabled
Processing time	2 minutes 49 seconds
Orthomosaic	
Size	46,394 x 39,133
Coordinate system	WGS 84 (EPSG::4326)
Channels	3, uint8
Blending mode	Mosaic
Reconstruction parameters	
Surface	DEM
Enable color correction	No
Processing time	21 minutes 51 seconds
Software	
Version	1.2.7 build 3100
Platform	Windows 64 bit

Appendix 8. Adjustment process



Appendix 9. Heurictic scores for variables

Access to Road

Class	Score
Direct access	1
No access or indirect access	0

Access to Waterway

Class	Score
With access	1
Without access	0

Depth

Class	Score
Less than 0,5 m	5
0,5 - 1,5 m	4
1,5 - 2,5 m	3
2,5 - 3,5 m	2
More than 3,5 m	1

Road Functional Class

Class	Score
Collector road	5
Local street	3
Neighborhood street	1

Sea View

Class	Score
With view	1
Without view	0

Frontage

Class	Score
19,1 – 25 m	5
13,1 – 19 m	4
7,1 – 13 m	3
1- 7 m	2
0 - 0,9 m	1

Distance to Land

Class	Score
0 – 91,9 m	5
92 – 183,8 m	4

183,9 – 275,7 m	3
275,8 – 367,6 m	2
367,7 – 459,5	1

Distance to Market

Class	Score
0 – 346,4 m	5
346,5 - 692,8 m	4
692,9 – 1.039,2 m	3
1.039,3 – 1.385,5 m	2
1.385,6 – 1.732 m	1

Distance to Port

Class	Score
0 - 83,7 m	5
83,8 - 166,8 m	4
166,9 – 250 m	3
250,1 – 333 m	2
333,1 – 417 m	1

Appendix 10. Additional analysis of statistical model

Ac_water dan se_view as the insignificant variables are eliminated in the next model (called Model B). We run model Model B with 7 predictors with a check for collinearity issues.

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.	Collinearity Statistics Tolerance	Collinearity Statistics VIF
1	(Constant)	7.777	.108		72.098	.000		
	ac_road	-.124	.042	-.069	-2.953	.003	.198	5.052
	road_cl	.075	.008	.132	9.031	<.001	.506	1.975
	di_port	.071	.010	.094	6.821	<.001	.560	1.785
	di_markt	.572	.010	.689	56.916	.000	.734	1.363
	di_land	.259	.013	.331	19.746	<.001	.383	2.614
	depth	.251	.014	.281	18.427	<.001	.462	2.166
	front	.086	.032	.057	2.687	.007	.241	4.149

a. Dependent Variable: ln_landvalue

The table shows that the variable ac_road still has a negative coefficient (-0,124). It also gives tolerance value below 0,2 (which is 0,198), and VIF more than 5 (VIF=5,052). These values are indicating ac_road has moderate to high multicollinearity. Other variables have VIF values below 5, except for front (VIF = 4,149, which is still acceptable). Then, it is important to check the correlation matrix between ac_road and other predictors. If they are highly correlated (above 0,7-0,8) we need to consider removing one of them. Below is the correlation matrix:

Correlations

		ac_road	road_cl	di_port	di_markt	di_land	depth	front
ac_road	Pearson Correlation	1	.682**	-.145**	.044*	-.047*	-.048*	.871**
	Sig. (2-tailed)		.000	<.001	.031	.021	.019	.000
	N	2419	2419	2419	2419	2419	2419	2419
road_cl	Pearson Correlation	.682**	1	-.235**	.168**	.020	.025	.594**
	Sig. (2-tailed)	.000		<.001	<.001	.316	.213	<.001
	N	2419	2419	2419	2419	2419	2419	2419
di_port	Pearson Correlation	-.145**	-.235**	1	-.368**	-.490**	-.426**	-.141**
	Sig. (2-tailed)	<.001	<.001		<.001	<.001	<.001	<.001
	N	2419	2419	2419	2419	2419	2419	2419
di_markt	Pearson Correlation	.044*	.168**	-.368**	1	-.087**	.081**	.047*
	Sig. (2-tailed)	.031	<.001	<.001		<.001	<.001	.021
	N	2419	2419	2419	2419	2419	2419	2419
di_land	Pearson Correlation	-.047*	.020	-.490**	-.087**	1	.719**	-.046*
	Sig. (2-tailed)	.021	.316	<.001	<.001		.000	.023
	N	2419	2419	2419	2419	2419	2419	2419
depth	Pearson Correlation	-.048*	.025	-.426**	.081**	.719**	1	-.053**
	Sig. (2-tailed)	.019	.213	<.001	<.001	.000		.009
	N	2419	2419	2419	2419	2419	2419	2419
front	Pearson Correlation	.871**	.594**	-.141**	.047*	-.046*	-.053**	1
	Sig. (2-tailed)	.000	<.001	<.001	.021	.023	.009	
	N	2419	2419	2419	2419	2419	2419	2419

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

The result shows ac_road has a very high correlation with front (r = 0,871), moderate correlation with road_cl (r = 0,682), and low to weak correlations with the remaining variables. Since ac_road and front are highly related, including both may cause redundancy in the model, and hence we choose to remove one of them. In this case, ac_road is then eliminated as it is also has negative impact and counterintuitive. We then develop a Model C

Below is the result of the Model C:

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.860[a]	.740	.739	.38308

a. Predictors: (Constant), front, di_land, di_markt, road_cl, di_port, depth

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1006.293	6	167.715	1142.865	.000[b]
	Residual	353.961	2412	.147		
	Total	1360.254	2418			

a. Dependent Variable: ln_landvalue

b. Predictors: (Constant), front, di_land, di_markt, road_cl, di_port, depth

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	7.824	.107		73.209	.000		
	road_cl	.064	.008	.114	8.572	<.001	.615	1.626
	di_port	.071	.010	.095	6.870	<.001	.560	1.784
	di_markt	.575	.010	.692	57.242	.000	.738	1.354
	di_land	.261	.013	.333	19.867	<.001	.383	2.609
	depth	.251	.014	.281	18.376	<.001	.462	2.166
	front	.012	.020	.008	.586	.558	.634	1.576

a. Dependent Variable: ln_landvalue

The t-test still shows one unsignificant predictor (front, with Sig. 0,558).

We need to remove this variable to build a new statistical model (Model D)

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.860[a]	.740	.739	.38303

a. Predictors: (Constant), depth, road_cl, di_markt, di_port, di_land

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1006.242	5	201.248	1371.742	.000[b]
	Residual	354.012	2413	.147		
	Total	1360.254	2418			

a. Dependent Variable: ln_landvalue

b. Predictors: (Constant), depth, road_cl, di_markt, di_port, di_land

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	7.845	.100		78.105	.000		
	road_cl	.067	.006	.118	10.955	<.001	.929	1.076
	di_port	.071	.010	.095	6.845	<.001	.565	1.771
	di_markt	.574	.010	.691	57.466	.000	.746	1.341
	di_land	.261	.013	.333	19.872	<.001	.385	2.599
	depth	.250	.014	.281	18.369	<.001	.462	2.164

a. Dependent Variable: ln_landvalue

Collinearity Diagnostics[a]

Model	Dimension	Eigenvalue	Condition Index	Variance Proportions					
				(Constant)	road_cl	di_port	di_markt	di_land	depth
1	1	5.645	1.000	.00	.00	.00	.00	.00	.00
	2	.176	5.669	.00	.76	.05	.00	.00	.00
	3	.114	7.031	.00	.09	.20	.00	.04	.04
	4	.046	11.043	.00	.09	.06	.44	.05	.02
	5	.014	20.188	.02	.01	.02	.00	.50	.93
	6	.005	35.206	.97	.04	.68	.55	.41	.01

a. Dependent Variable: ln_landvalue

Using the remaining five predictors (road_cl, di_port, di_markt, di_land, depth) in Model D, we find there are no issues of unsignificant variables and collinearity. The R-square is 0,740, meaning 74% of the variance in land value (ln_landvalue) is explained by the model. Adjusted R-square of 0,739 is very close to R-square, suggesting good model fit without overfitting. The standard error is 0,38308, indicating relatively good precision of predictions.