



# Land Use Changes Assessment using a triangulated framework: Perception Interviews, Land-Use/Land Cover Observation, and Spatial Planning Analysis in Tanjung Batu and Derawan Island, Indonesia

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## Abstract

Understanding land-use change is imperative in the management of Indonesian coastal ecosystems with numerous environmental impacts generated from land-use conversion. To assess these impacts in holistic perspective, we use three sources of data, land cover change, policy maps, and interviews, to triangulate the main issues. Combining these sources, we analyze land-use changes in the past based on perception interviews and secondary data from the government spatial plan policy map and observable land-cover. In Tanjung Batu and Derawan Island we found that local populations were more aware of the changes related to infrastructure development, but that there are discrepancies between assigned and actual land-use, illustrating the value of a triangulated framework.

**Keywords** Triangulated framework · Local perspectives · Mangroves · Land-use change · Spatial policy map

## Introduction

Indonesia is a maritime country with 17,504 islands and 95,181 km of total coastline with ecosystems that offer diverse ecosystem services that are important at local (e.g., fishing ground) and global scales (e.g., carbon sequestration) (Sukardjo and Pratiwi 2015). Nevertheless, Indonesia's coastal environments are currently under pressure from government plans concentrating on major investment, such as those for the northern coast of Java (Suroso and Firman 2018). Population growth has forced the Indonesian government to intensify and diversify the utilization of coastal and marine resources, which has led to a decline of their ecosystem service resources (Hutomo and Moosa 2005). With

increasing population, food demands have risen, resulting in overexploitation of resources, further exacerbating the vulnerability of coastal and marine ecosystems (Pomeroy et al. 2007). In this study, we particularly focus on land-use conversion.

In addition to referring to human use, the term land-use is also used to include social and economic purposes (IPCC 2000; Kim 2016). Although land-use changes can be beneficial, e.g., forest conversion, there is evidence that land-use changes in Indonesia are socially sub-optimal (Pagiola 2000). In coastal areas, land-use changes have affected rates of erosion and sedimentation (Sanjoto et al. 2019), which in turn affects delivery of essential services such as coastal protection, economic benefits from tourism, and climate change adaptation (Wylie et al. 2016).

The shifting values and perceptions of residents of coastal areas regarding land-use changes are gaining salience, particularly for the sustainability of conversion efforts. Recent studies of community perceptions (e.g., Lukman et al. 2020; Quevedo et al. 2020a, b, 2021b, c) highlight the importance of local stakeholders in identifying threats and badly planned management strategies to better achieve sustainable management of coastal resources, particularly blue carbon ecosystems. We use environmental cognition theory to examine people's perceptions of, and subsequent responses to environmental changes (Meyfroidt 2013).

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Remote sensing is commonly used to identify land-use change, although it does have limitations. For example, it cannot take account of the sensitive phases of crop cycles and farmers’ awareness and perceptions of them (Fonta et al. 2015). To date, there are many scientific studies that examine the role of people’s perceptions in investigating and understanding land-use changes (e.g., de Almeida et al. 2016; Lee et al. 2008) There is also a growing body of research using public perceptions of land-use changes to complement remotely sensed data (e.g., Ariti et al. 2015, in Ethiopia; Munthali et al. 2019, in Central Malawi).

In Indonesia, there also several studies that use public perceptions of land-use changes. Kikuyama et al. (2018) argue that an understanding of people’s perceptions is vital to establishing the status and causes of many coastal problems through identification of countermeasures (e.g., for land erosion) and promotion of sustainable land-use. In North Sumatra, a Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis showed that mangrove ecotourism is a sustainable form of land-use and local people’s perceptions are important for successful mangrove conservation (Basyuni et al. 2018). In Borneo, communities’ perceptions of the negative impacts of palm-oil land-use conversion on the environment and their own livelihoods were essential to mobilizing opposition (Abram et al. 2017). Based on our extensive review, the use of public perceptions to identify land-use changes, particularly in coastal ecosystems in Indonesia, is not yet well-established. We conducted this study to fill this research gap (Tables 1 and 2), using a triangulating framework approach (Fig. 1) to better encapsulate land-use changes and its causal drivers in the coastal ecosystems of Indonesia.

Through a review of existing literature on the use of local perceptions in land-use change analysis we identify certain research and methodological gaps (Tables 1 and 2). These indicate how land-use change studies were conducted using remote sensing data combined with interviews to supplement the analysis and provide further understanding on the causal drivers of land-use change. Based on this summary, we found there is still a limitation on this combined approach at the human scale of the study, e.g., socio-demographics of the analysis.

Specifically, we investigated land-use change in Tanjung Batu and Derawan Island in Berau Regency, East Kalimantan. Our triangulating framework uses three datasets: local perceptions of land-use change, which provide our primary data, and land-use/land-cover (LULC) maps based on remotely sensed data and spatial plan policy maps, which comprise our secondary data. We propose this framework to provide a holistic approach of understanding the land-use change, its drivers and existing policy strategies. To our knowledge, this framework has not to date been used in studies of land-use changes in Indonesia.

**Table 1** Summary: The Studies of Perceptions in the Context of Land-Use Change

Authors	Title	Methodologies	Gaps
Hur et al. 2010	Neighborhood satisfaction, physical and perceived naturalness and openness	GIS data and resident surveys to assess the environment and resident responses	(1) Uncertainty due to the response rate; (2) In-person interviews may get better response rate
de Almeida et al. 2016	Human perceptions of landscape change: The case of a monodominant forest of <i>Attalea speciosa</i> Mart ex. Spreng (Northeast Brazil)	Synthesizing and comparing historical documents and local perceptions on landscape change	(1) Participatory methodologies for collecting perceptions is challenging; (2) Supplement data from satellite images and individual interviews
Lee et al. 2008	Relationship between landscape structure and neighborhood satisfaction in urbanized areas	Mail-out survey and landscape measurement with NDVI method	(1) Neighborhood scale and (2) consideration to apply the approach in greater scale
Munthali et al. 2019	Local Perceptions of Drivers of Land-Use and Land-Cover Change Dynamics across Dedza District Central Malawi Region	Mixed method of remote sensing and GIS-based analysis, focus group discussions, key informant and semi-structured interviews	To include the investigation on the impact and consequences of LULC changes on rural livelihoods

**Table 2** Categorization to Identify the Gaps

Sub-section	Categorization of Gaps
<b>Socio-ecological intersection</b> (Local perceptions and LULC maps)	a.) Identify the perceived changes by the locals compared with the actual changes captured in the LULC maps b.) Identify the perceived impacts of the changes by the locals compared with the actual changes captured in the LULC maps
<b>Environmental impact of policy</b> (Policy map and LULC maps)	a.) Identify the gaps of the difference between assigned land-use and land-cover in the spatial plan policy map and the LULC map
<b>Social impact of policy</b> (Policy map and local perceptions)	a.) Identify the gaps of potential threat from spatial plan not captured by perception

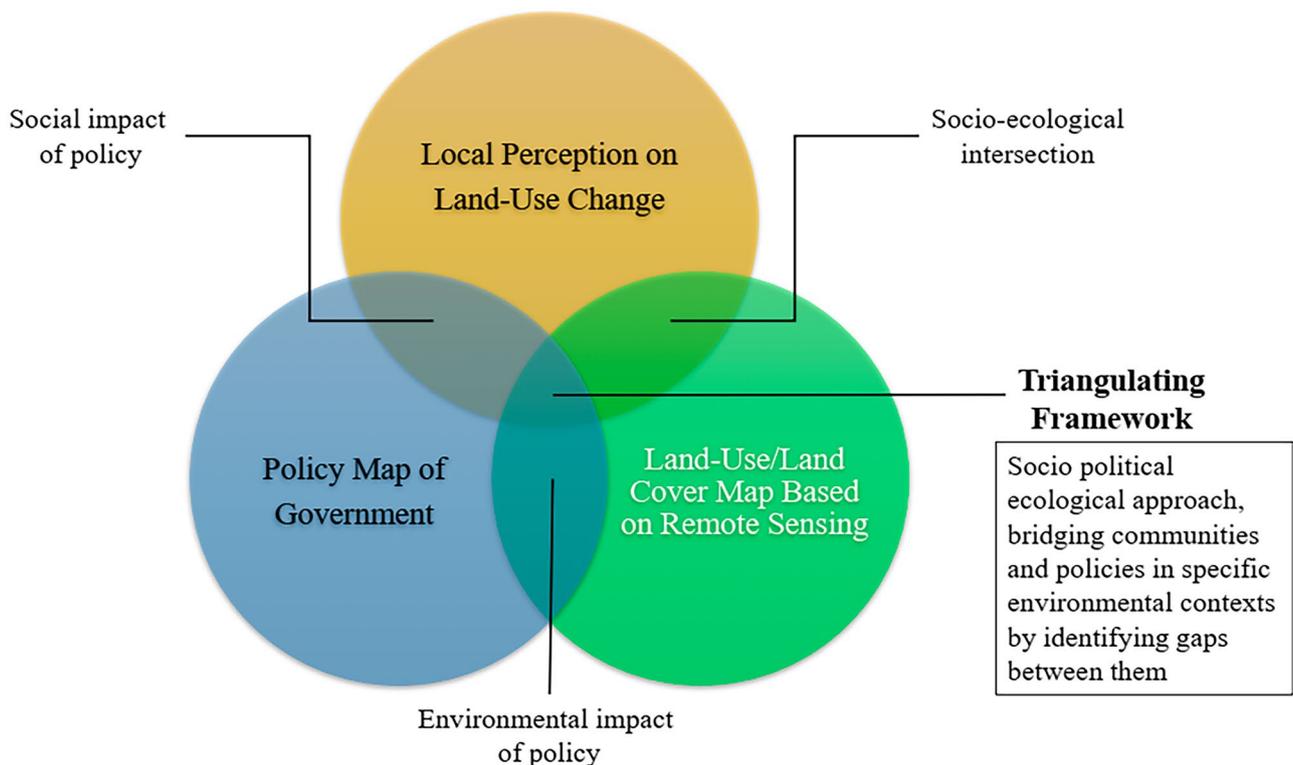
## Materials and Methodology

### Study Sites and Research Design

We conducted this study in Tanjung Batu and Derawan Island in Berau Regency, East Kalimantan province, Indonesia (Figs. 2 and 3). The province generates 1,647.5 metric tons of aquaculture products from brackish water ponds and has a growing sector in coal mining, with 15.29 million metric tons of coal produced in 2010, and 35.11 million metric tons in 2015 (BPS Kabupaten Berau 2018). Berau district is rich in forestry, mining, and fishery resources, and with decentralization, the district government gained more political control over the management of these natural resources

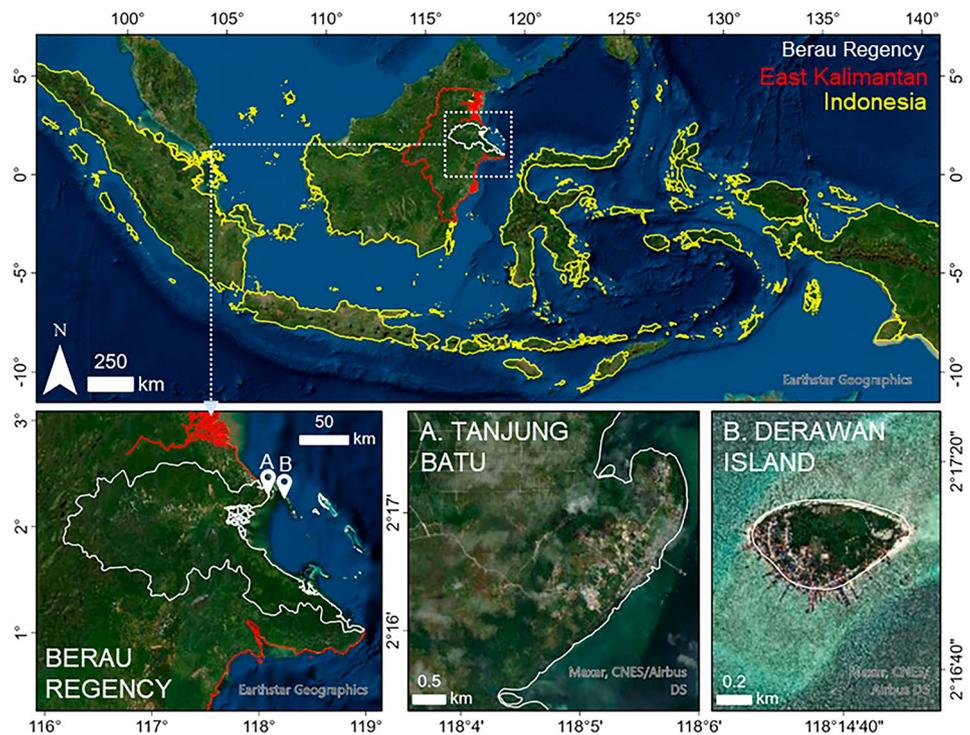
(Kusumawati and Visser 2016). Land-use conversions have resulted from rapid loss of mangrove cover in the province (Richards and Friess 2016; Malik et al. 2016). In contrast, the Provincial Spatial Plan (*Rencana Tata Ruang Wilayah*) of East Kalimantan contains several detailed regulations prohibiting certain activities to protect the mangrove ecosystems and recognizes their status as fish nurseries and tourist destinations (Lukman et al. 2019).

Berau Regency is known for its tourism sector. For instance, Derawan Island is famous for its coral reefs, which attract diving and snorkeling enthusiasts, while Tanjung Batu is known for its mangrove forests (Mukhlisi 2017). In terms of existing environmental protection programs, the Berau Regency Policy No.8/2014, which covers Coastal



**Fig. 1** Triangulating Framework with our three datasets

**Fig. 2** Map of the study sites' locations



Areas and Small Islands Zoning Plan (RZWP3K), includes development and establishment of conservation areas where biodiversity, ecosystems, and water quality are protected.

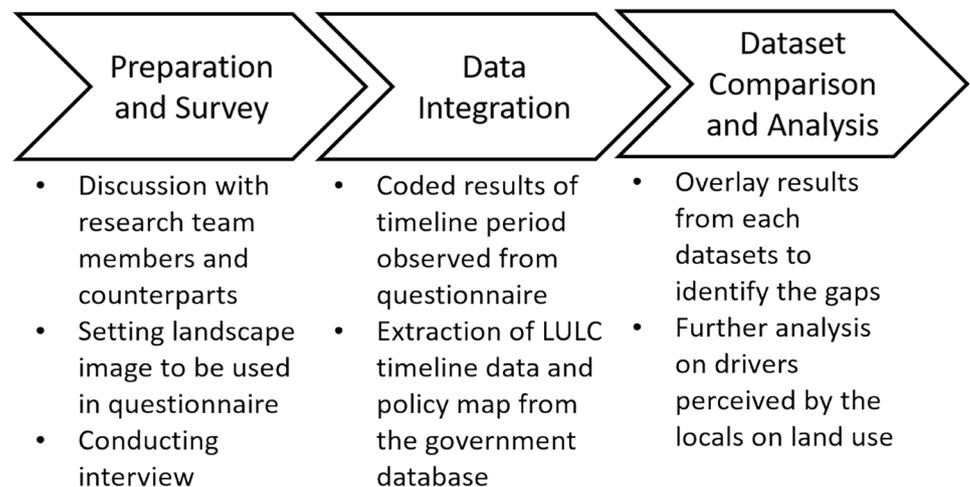
### Perceptions of land-use changes

We selected our respondents from the residents of Tanjung Batu and Derawan Island. We calculated sample size for the land-use changes perception using Cochran's formula. Cochran's formula is a procedure for determining appropriate sample size in survey research based on two key factors of the margin of error and the alpha level (Bartlett et al. 2001). To determine the ideal sample size for respondents'

perception, this study refers to the populations of Tanjung Batu (4,388) and Derawan Island (1,515) in 2019. Following Initially, Quevedo et al. (2021a), we set the margin of error at 14–15% and alpha level of 0.05. However, due to the limited time for the survey, we were only able to interview a total of 27 respondents from Tanjung Batu and 24 from Derawan Island, increasing the margin of error to 19 and 20% respectively. A local NGO (TNC – The Nature Conservancy) assisted in the selection of key respondents (e.g., the head of community organizations).

We developed a semi-structured questionnaire in two parts to guide our participant interviews: the first section identified socio-demographics attributes (modified from

**Fig. 3** Research Implementation



Lukman et al. 2020) on the age, gender, marital status, occupation, education, and length of residence in the area. The second part addressed perceptions of and explanations for land-use changes, and we used satellite images of each site (derived from Google Earth) to document the location of changes listed by our respondents. The map for Tanjung Batu showed landmarks such as the port, the main road, government facilities, and tourism destinations, and for Derawan Island the entire island. We embedded gridlines in the maps to help respondents locate LULC changes.

### Land-Use/Land Cover Maps

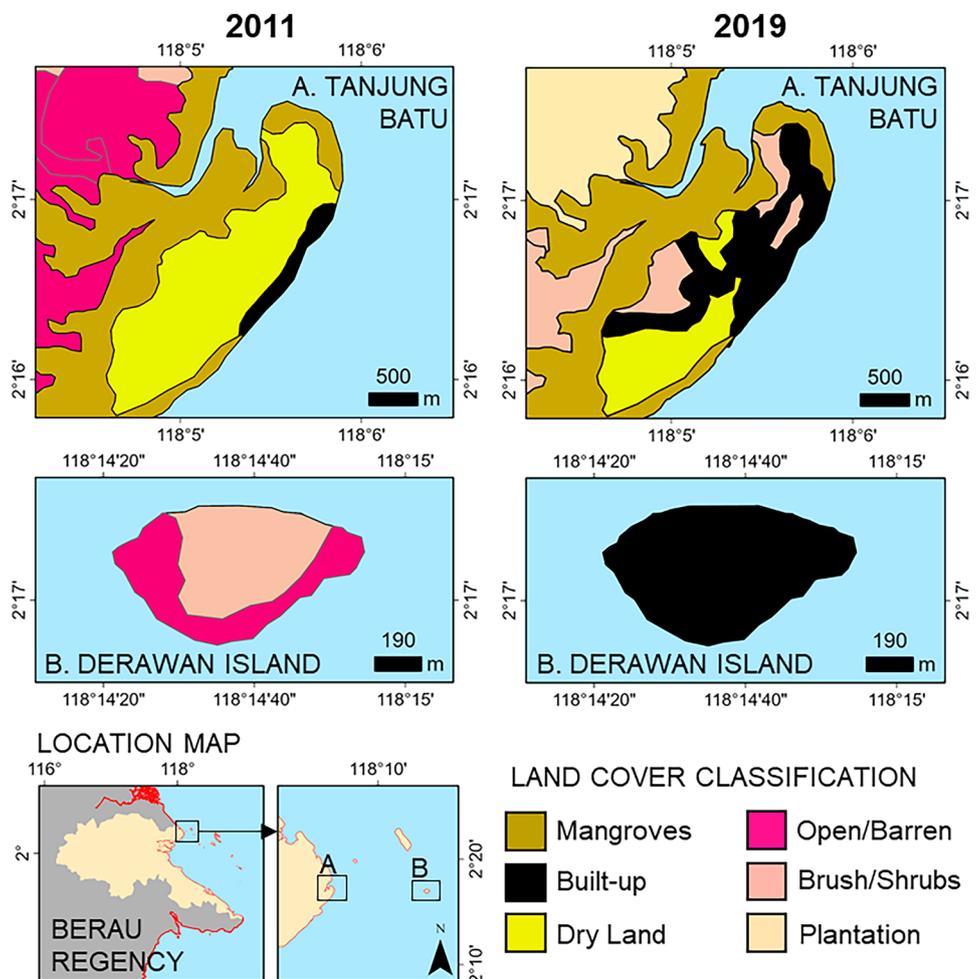
We obtained land cover maps for East Kalimantan province including our study sites from the Ministry of Environment and Forestry. According their website, the LULC maps for period 2009 onwards are based on Landsat data, and are used, among other things, for land management planning and development. No further actions (e.g., georeferencing, interpolation) were undertaken. Since the maps are made available in shapefiles they are compatible with the software

ArcGIS pro v.2.6.2. We used only the years 2011 and 2019 (Fig. 4) because of the visible changes in the study areas and our respondents’ reported timing of changes. Berau Regency was declared a Marine Protected Area in 2005 due to its high biodiversity (TNC 2008). Despite such measures, 60,906 ha of mangrove deforestation occurred between 2000–2012, mainly due to the expansion of the aquaculture sector, clearly visible in certain regions such as Kalimantan and Sulawesi (Richards and Friess 2016). The aquaculture sector expanded between 1997–2008 from 162.5 ha to 3,624.9 ha (Permana 2012).

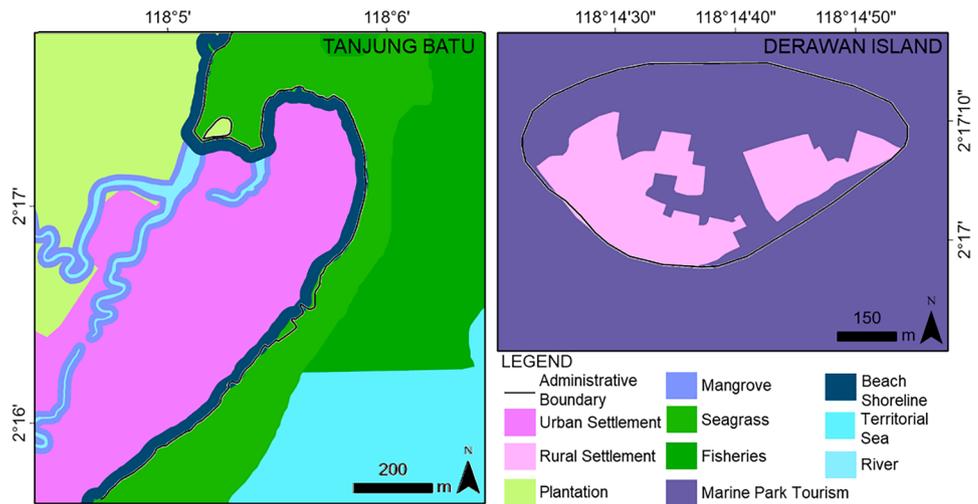
### Spatial Plan Policy Maps

We also utilized policy maps covering the period from 2016 to 2036 (*Rencana Tata Ruang Wilayah Kabupaten Berau Tahun 2016–2036*) to assess how local governments at our study sites perceived and managed land (Fig. 5). Berau Regency Policy No. 9/2017, available for download in shapefile format since December 2019, is a spatial plan

**Fig. 4** LULC map of the study sites for 2011 and 2019



**Fig. 5** Spatial plan policy maps of the study sites



containing the details and explanations of different land uses in accordance with government land-use categories. Consequently, we were not able to access the complete document and our study is limited to spatial plan policy maps showing different land uses (eight categories), one area of jurisdiction, and one landscape feature (Fig. 5).

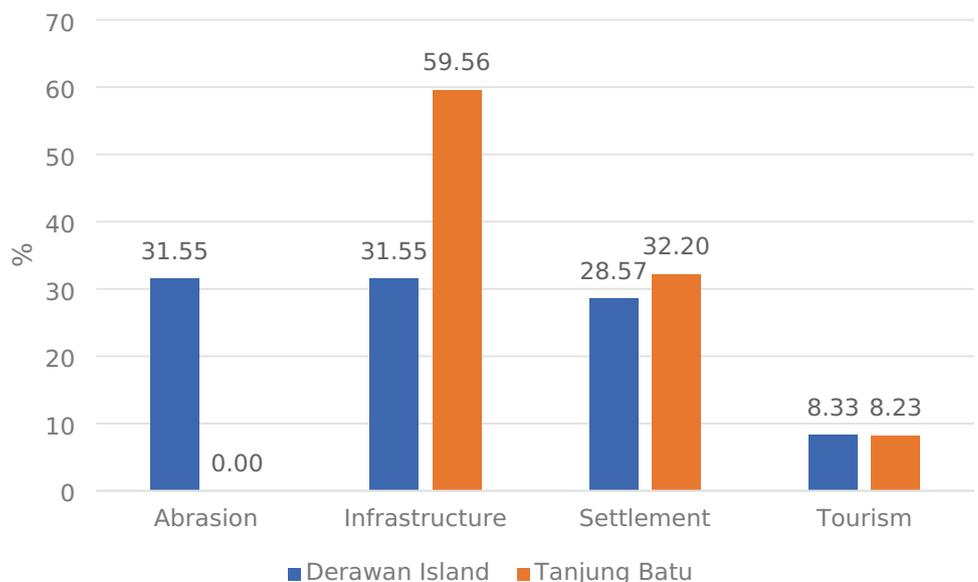
The center of Tanjung Batu is urban settlements, surrounded by plantations, mangrove (categorized separately (*mangrove/bakau*)), beach shoreline, and a river. The coastal and ocean spatial plan shows categories such as seagrass and fisheries, in addition to the extent of jurisdiction from the shoreline. The Derawan Island map shows village settlement and the marine park tourism along the shoreline as well as inland. Outside the boundaries of the marine park tourism area, the fisheries and the area of jurisdiction from the shoreline are marked.

## Results

### Perceptions of Land-use Change in the Study Sites

Based on the interview data from our 27 respondents in Tanjung Batu, we categorized three drivers of LULC: infrastructure development (59.56%, 246 citations), settlement development (32.2%, 133 citations), and tourism development in the form of mangrove center building (8.23%, 34 citations). In Derawan Island interview data from our 24 respondents, we categorized four drivers of LULC: infrastructure development and abrasion (31.55%, 53 citations), settlement development (28.57%, 48 citations), and tourism development (8.33%, 14 citations) (Fig. 6). In both groups, citations of tourism as the driver of LULC are relatively low, while Derawan Island respondents cited infrastructure

**Fig. 6** Perception of the Drivers of Land-Use Change

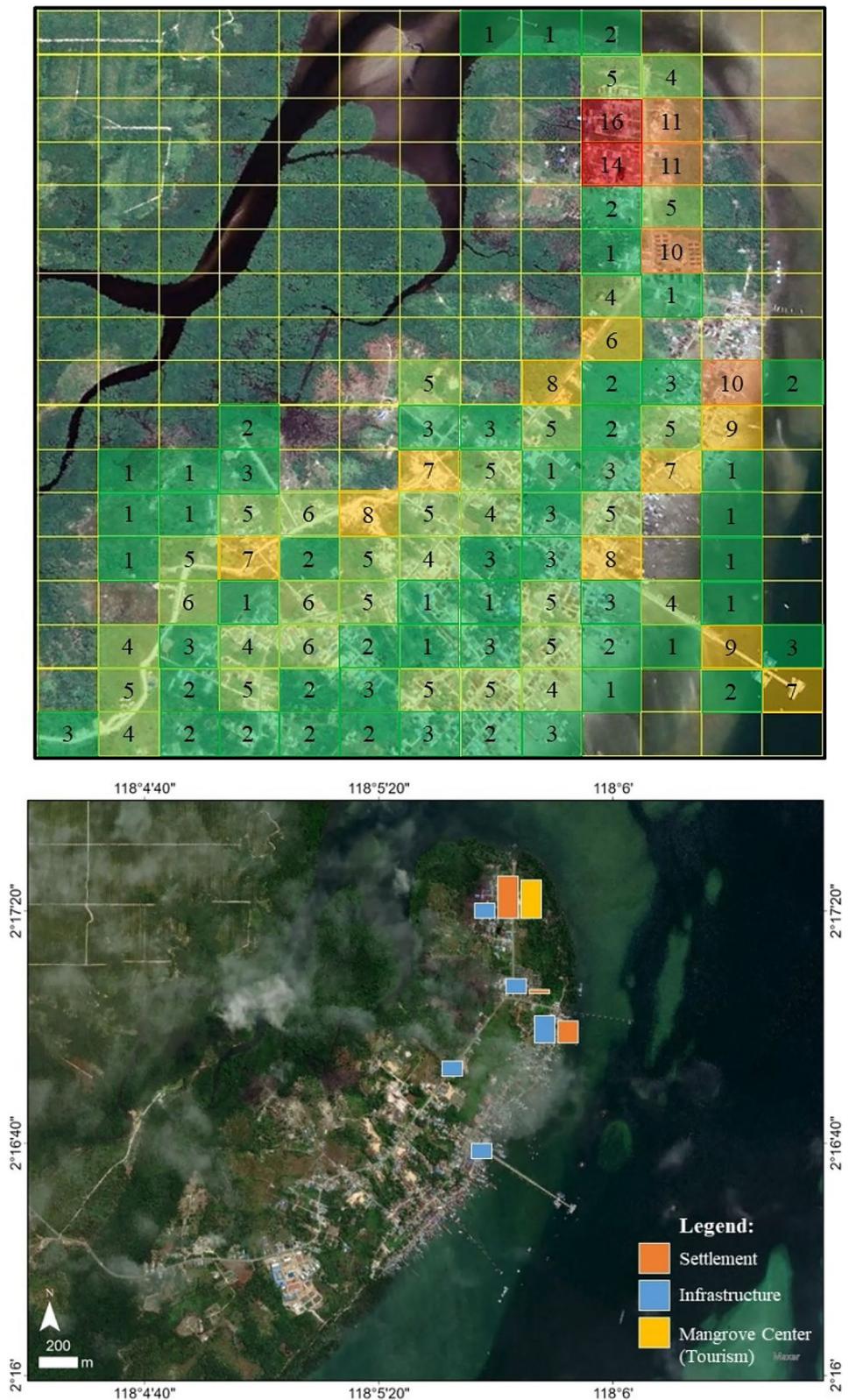


abrasion as a driver in addition to infrastructure development, as highlighted in Tanjung Batu.

Respondents in Tanjung Batu noted that the drivers of LULC in the north were influenced by the establishment

of a mangrove center that serves as tourism infrastructure. They also highlighted road and port construction as increasing the accessibility of Tanjung Batu as the tourism hub for Derawan Island, and mentions additional infrastructure

**Fig. 7** Perception Map of Land-Use Change Drivers—Tanjung Batu (top: distribution of the frequency perceived by respondents; bottom: type of drivers perceived with the height of the bar illustrate the frequency) [Satellite image year 2018, Source: USGS]



such as a school and an athletes’ dormitory that was used in National Sports Week (PON) in 2008. Regarding settlement respondents highlighted two areas: the first near the coastal shoreline, with the expanding settlement from the increasing population, and the second in the north, relatively close to the mangrove center tourism area (Fig. 7).

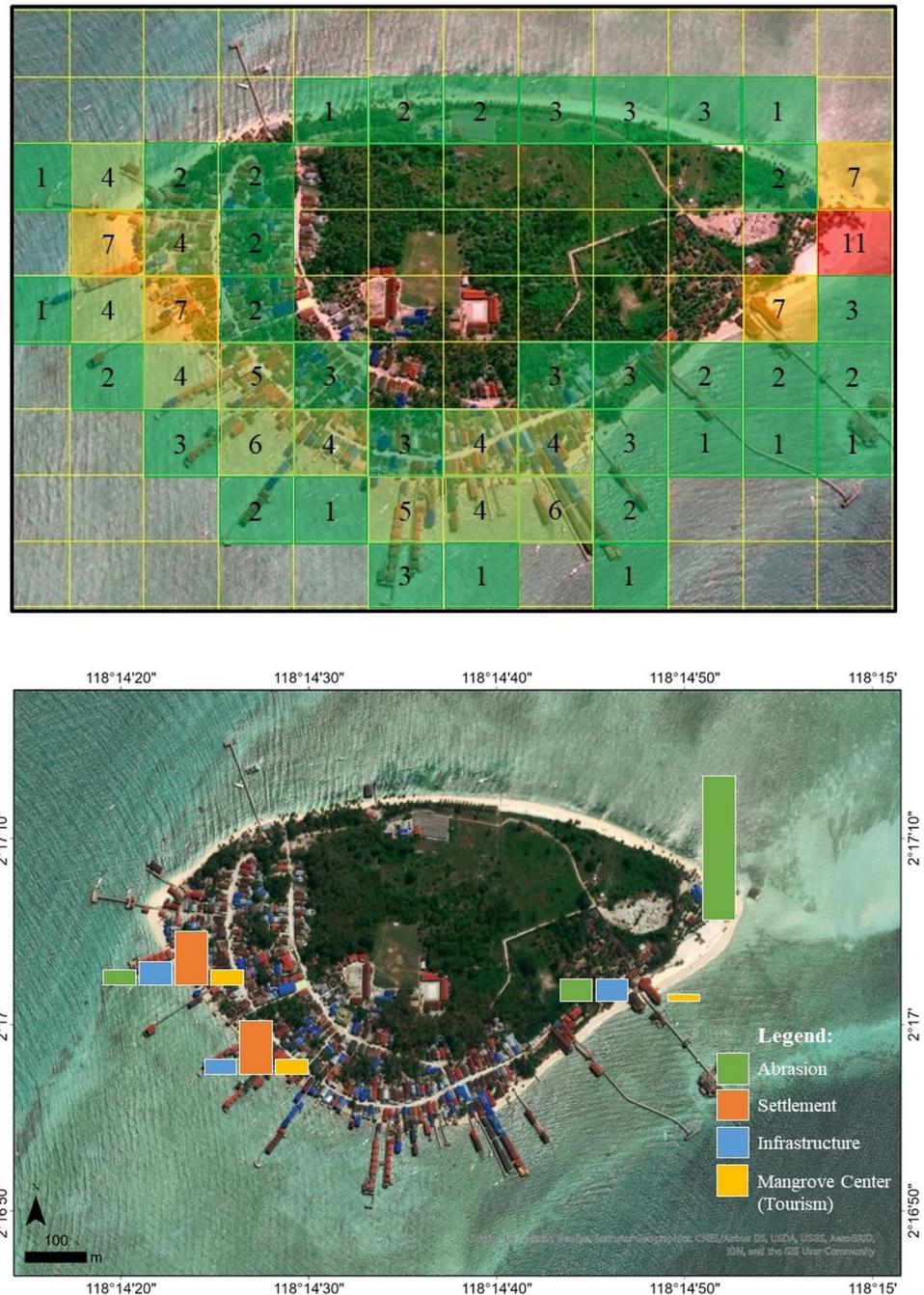
Derawan Island respondents perceived slightly different drivers of LULC changes. In addition to those noted above they also cited abrasion on the eastern part of the island, and six noted that this abrasion occurred because of mismanagement of resort construction and the impacts of the

development (Fig. 8). On the coastal shoreline of the western and southern part of the island they attribute LULC changes to settlement development. Interestingly, they did not attribute as much to the tourism sector.

**LULC Change: 2011 and 2019**

In the 2019 LULC map of Tanjung Batu, the expansion of settlement land-coverage is noticeable, in some cases replacing dry fields. Several bushes cover areas near the expanded settlement areas. Outside the settlement coverage,

**Fig. 8** Perception Map of Land-Use Change Drivers – Derawan Island (top: distribution of the frequency perceived by respondents; bottom: type of drivers perceived with the height of the bar illustrate the frequency) [Satellite image year 2018, Source: USGS]



in northwest Tanjung Batu, there is also conversion of open fields into plantations. However, it is interesting to note the relatively large intact areas of mangrove ecosystems that remain. For Derawan Island, the database of LULC map showed that in 2011 LULC is categorized into two types of open fields and bushes, but by 2019, the whole island been converted into settlement coverage. Based on our field observations, while coastal areas are mostly filled with settlements, parts of the island with coverage of bushes remain. Although our study is limited in terms of the map resolution, we nonetheless argue that this an opportunity for our triangulating framework to contribute to both spatial plan perspectives and changes perceived by the community. On the 2019 Spatial Plan map, the area of Derawan Island (*Kepulauan Derawan*) is acknowledged as a strategic zone for environmental conservation and tourism. We argue that the changes of LULC in Derawan Island are related to tourism, as we discuss below. In addition, we also found discrepancies between the LULC maps and the spatial plan map, for example between the assigned and actual ecosystems.

### Discrepancies Among Survey Data, LULC Maps, and Government Spatial Plan Maps

We identified gaps on the LULC maps between perceptions of land-use and actual land-use (Fig. 1, Table 3) as the socio-ecological intersection in which maps from remote sensing technology can objectively detect the results of the land-use change. However, in reality, our respondents expressed their own perceptions on the causes of change. The remote sensing map can identify the change of land-use shown as land-cover change, and local perceptions can provide information on land-use change drivers. In Tanjung Batu, the land-use changes from infrastructure development were most frequently cited by respondents. In Derawan Island the respondents cited abrasion as a driver change in land cover in addition to expanding settlement. It is noteworthy that the vegetation and bush land cover we observed were not mentioned in the perception interviews.

Results obtained from the LULC maps and policy map complement each other, an intersection we describe the environmental impact policy. Both study sites illustrate how the LULC maps can support this formulation by the local government, however we found gaps and different results especially from the policy map with various areas in different land-use categories from the LULC maps. In context of Tanjung Batu, the gaps between LULC maps and policy map were related to the assigned ecosystem conservation area. According to the East Kalimantan province spatial plan policy, seagrass and mangrove ecosystems were included in the category of fisheries focusing on ocean conservation and marine park tourism. The policy treated mangroves

**Table 3** Identified Gaps within Three Sub-Sections of Triangulating Framework

Sub-section	Identified Gaps	Complementing Aspects
<b>Socio-ecological intersection (Local perceptions and LULC maps)</b>	<ul style="list-style-type: none"> <li>a.) The perceptions of drivers and causes of the changes from the respondents should be further investigated for clarification and verification to identify the factor of the changes of the LULC. For example, the perceived abrasion phenomenon in Derawan Island</li> </ul>	<ul style="list-style-type: none"> <li>a.) Perceptions provide another layer of information with the drivers and causes of the changes in the LULC maps</li> <li>b.) The settlement growth (Tanjung Batu) was reported in the LULC maps and also perceived by the locals</li> <li>c.) Certain impactful environmental change was perceived such as the abrasion (Derawan Island) with socio-ecological phenomenon details, such as historical land-use</li> </ul>
<b>Environmental impact of policy (Policy map and LULC maps)</b>	<ul style="list-style-type: none"> <li>a.) Duality of function between residential and tourism (Derawan Island)</li> <li>b.) Identified gaps on the assigned ecosystem in the LULC maps and the assigned ecosystem in the spatial plan policy map, for example the seagrass-mangrove ecosystem (Tanjung Batu), and settlement-tourism (Derawan Island)</li> </ul>	<ul style="list-style-type: none"> <li>a.) LULC maps can serve the role as a basis for the policy formulation, for example the assigned mangrove and seagrass ecosystem (Tanjung Batu)</li> </ul>
<b>Social impact of policy (Policy map and local perceptions)</b>	<ul style="list-style-type: none"> <li>a.) Identified the gaps of potential threat from spatial plan not captured by perception from neighboring area such as plantation expansion (Tanjung Batu), and the terrestrial tourism expansion (Derawan Island)</li> </ul>	<ul style="list-style-type: none"> <li>a.) Perception as an input and assessment tool for the policy implementation, for example in the tourism sector (Derawan Island)</li> </ul>

and seagrass in a similar manner; for example, in Article 50 point 7 for the regulation of the coastal shoreline zone, mangrove and seagrass are stated as indicators for protected areas and any activities that could threaten such ecosystems are forbidden. However, the policy map does not highlight the mangrove ecosystems. This can be a concern if the government is ignoring or misinterpreting the ecosystems, as the policy map highlights seagrass more in mangrove ecosystems. In Derawan Island, the settlement indicated by the LULC maps supports the policy map's categorization as a village settlement area. However, if we consider the results from the perception interviews, some of the settlements were in fact used to support terrestrial tourism, providing cottages and restaurants, among other services. Thus, there is concern the overlap between settlement and tourism areas could potentially overestimate the island's capacity to manage the tourism sector.

In the intersection between the perception and the policy, which we term the social impact of policy, both datasets can complement one another in the case of the social policy. For example, the spatial policy map defines the northwest side of Tanjung Batu as a plantation, in which the pressure of expansion could threaten the mangrove ecosystem, similar to the threats to the mangrove ecosystem in Suaran in the southern part of Berau. In Derawan Island, the spatial plan policy recognized its marine tourism sector. However, our observations indicate that the island itself is supporting an expanding its terrestrial tourism sector, with cottages and various other business activities. Understanding the capacity of island to support the local population and the tourism industry may prove essential for assessing its sustainability. Data on perceptions of these impacts can provide the government with an important input for the formulation of land management and development policies.

## Discussion

We discuss implications of local perceptions and LULC maps data for land-use policy and the need for a holistic approach based on the triangulating framework as well as land-use change to provide an understanding of the generation of local perceptions.

### Implication of Local Perceptions for Land-use Policy

Based on the interviews, most of our respondents' perceptions of land-use change were based on visible infrastructure development, i.e., road access, port construction, settlement expansion, and tourism facilities. Two interesting highlights are related to the Mangrove Center in Tanjung Batu. The Mangrove Tourism Center and its surrounding areas in

Tanjung Batu have additional infrastructure, such as ticket booths, wooden planks for road access, and office buildings. Most of the facilitators for the Mangrove Center were local fishermen, cooperating in a monitoring system to prevent the illegal logging of mangroves, although in recent years mangrove timber harvesting has become more sustainable (Ilman et al. 2016). However, according to our interviews the area remains under threat from illegal harvesting. Another area of concern is the aquaculture sector. In other areas of Berau Regency, such as Suaran and Pegat Batumbuk, the aquaculture sector is flourishing and has the potential to replace existing mangroves. Richards and Friess (2016) highlight evidence on the exploitation of mangrove ecosystems through aquaculture sector development in Kalimantan province. Local attention to infrastructure development and land-use change can provide useful input for government strategies to implement the spatial plan for the area. Due to lack of understanding of the impacts of certain infrastructure developments, local perceptions may be either positive or negative. For example, our respondents reported negative perceptions of the abrasion sites on Derawan Island (see below). The government should acknowledge such potential threats on the coastal ecosystem from the land-use change resulting from infrastructure development as it develops conservation strategies for the area, as well as social-impact of policy.

### Implication of LULC Maps for Land-use Policy

The majority of our respondents on Derawan Island noted the abrasion on the eastern side, and a few provided detailed explanations, citing villa development as the main cause of the abrasion. Although Derawan Island does not have a mangrove ecosystem, as the shift to tourism development expands land-use change may result in potential water shortages and natural disasters. Derawan Island is known for the beauty of its coastal areas (Purnamasari et al. 2015) as well as an important feeding ground for green sea turtles and dugong in its seagrass ecosystem (Christianen et al. 2012; van Katwijk et al. 2011). Since tourism is increasingly important for the economy, appropriate environment protections are essential to maintain the sustainability of local livelihoods and the island's ecosystems. Further research on local perceptions of land-use can serve to further verify the drivers of changes.

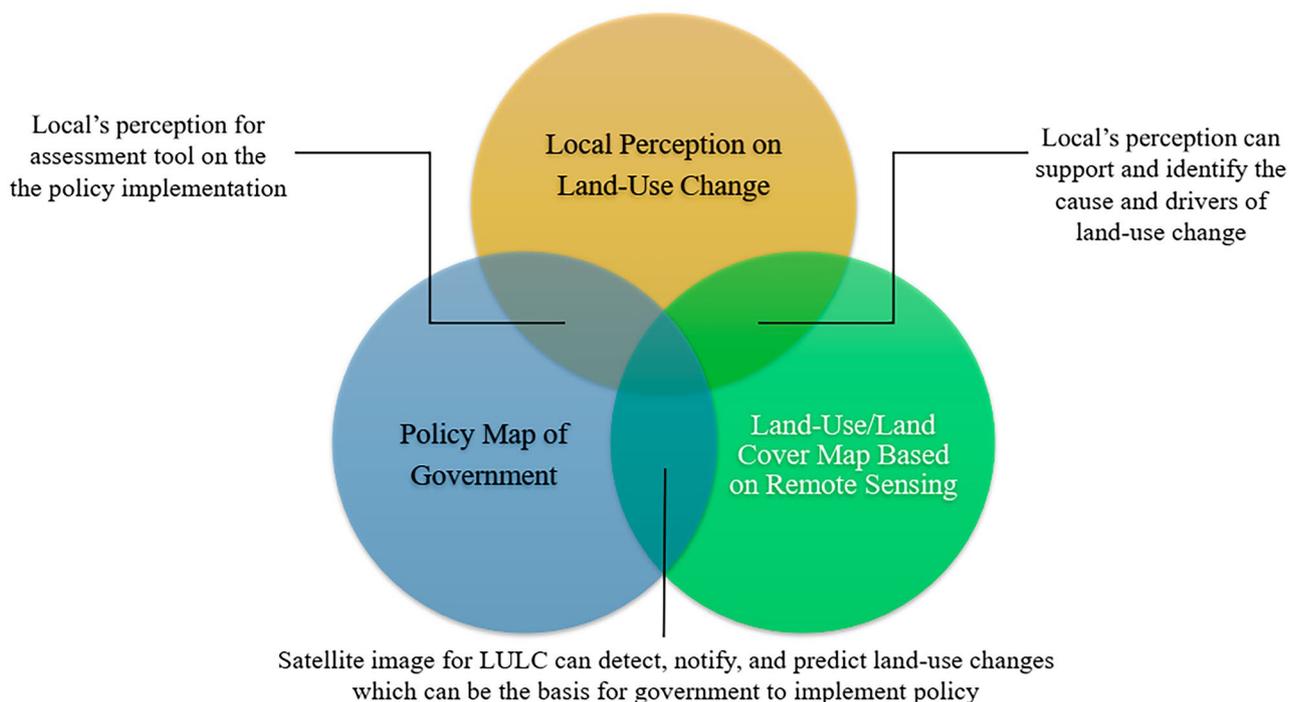
We found disturbing discrepancies between the policy map of Berau Regency and actual conditions on the ground. In Derawan Island, assigned land-use on the policy map potentially differed from actual land-use in terms of its capacity to facilitate and support the tourism industry as seen in the LULC maps results, with the notable increase of settlement from 2011 to 2019.

Another concern we highlight is the difference between the observed assigned ecosystems in the spatial plan and the current conditions in Tanjung Batu. During our field survey we found that the current mangrove tourism area was designated a seagrass ecosystem in the spatial plan. The fact that spatial plan regulations treat both types of ecosystem in a similar way could have possibly produced the confusion. The conditions we found during our survey and official policy land-use could indicate exploitation and mismanagement, thus efforts are required to eliminate such discrepancies between actual conditions and official designated land-use. A clear statement in the spatial plan could eliminate illegal conversion of coastal ecosystems, and a monitoring system should also be implemented with community participation that can support the government in protecting the coastal ecosystems.

### Holistic Approach of the Triangulating Framework

As tourism grows in Derawan Island, it is possible that local residents perceive a potential to use their residences as businesses to provide services to accommodate the requirements of the tourism sector, which in turn would increase pressure on the supporting capacity of the island. However, several of our respondents noted the issue of limited natural resources, notably ground water. Although the policy map stated that the spatial plan for Derawan Island can be categorized for two distinct uses (Village Settlement and Marine

Park Tourism), in reality there is the threat of the dual function of residence and supporting tourism. The data from LULC maps and enforcement of the policy should incorporate cooperation with the local community to maintain the island's capacity to accommodate tourism and at the same time to conserve its limited natural resources. The holistic approach of our triangulating framework can be utilized to address settlement growth in Tanjung Batu. Using the LULC maps to establish the current condition of the area, the government can formulate a spatial plan that takes into account social, ecological, and economic conditions for future development and involves local residents in decision-making related to such policy-making, while also incorporating their local knowledge and perceptions of potential positive or negative impacts of developments. Land-use conflicts have been reported due to increasing numbers of stakeholders with incompatible interests (Sinthumule et al. 2020). In Berau Regency, the marine conservation movement reported that the local elites were excluded from policy-making. However, positive engagement of government with local entrepreneurs and other stakeholders with their historical knowledge and interests in the conservation of their environment will be more likely to produce effective and sustainable policies (Kusumawati and Visser 2016). The holistic approach of our triangulating framework that combines the three different approaches (perceptions, policy map, and land-use) can serve as an example of a basis for the development of strategies for sustainable land management (Fig. 9).



**Fig. 9** Highlights of Triangulating Framework in the case of Tanjung Batu and Derawan Island

## Local Awareness of Land-use Change

Our research identified a discrepancy between the identification from LULC maps and our informant's responses. During the interviews, we aimed to allow the respondents to be pro-active in giving us insights by providing them limited but necessary information—chiefly the landmark of the landscape in the questionnaire. The “undetected” land-use change identified by the locals could be related to their awareness of their environment.

An individual's environment provides stimulus, although every individual responds to particular stimuli. There are variety of factors which can influence individual's attention, for example the internal factors of gender, age, and cultural values, as well as external factors from the dynamic of movement. According to Solso (2001), attention is mental concentration on several but not all stimuli in the surrounding environment, which explains how certain objects are ignored in favor of others of greater interest. In our interviews, we found that respondents perceived land-use change in form of infrastructure development, such as roads, which facilitate accessibility, or tourism facilities, which may impact their livelihoods, thus distracting their attention from static types of land-uses such as vegetation cover. This may explain why the drivers of land-use change from infrastructure development were cited by the majority of our respondents. The decrease of coastal areas in Derawan Island may be a significant environmental stimulus, drawing the attention of the community to the abrasion that has occurred following land-use changes, and hence to the vulnerability of their small island.

Gender also plays an important role in shaping attention. Liu et al. (2013) found that females are better than males at focusing their attention to the environment. In our study most respondents were male, so it is possible land-use changes in inland areas might have gone unnoticed, whereas land-use changes that have a significant impact on their livelihoods or their environment, as in the case of Derawan Island abrasion and the growing importance of the Mangrove Center in Tanjung Batu, have attracted their attention.

Another factor that may affect degree of attention to the environment is education. For example, programs such as the green ethos education program are designed to increase students' awareness of and concern for the environment (Kadiyono et al. 2019). Long-term educational activities and environmental awareness programs have been shown to influence individual behavior in terms of environmentally friendly choices and responses (Hafiar et al. 2019). Essoungong et al. (2020) report that farmers' knowledge, beliefs, and how they understand their surrounding environment, affect their perception and awareness of soil fertility and contribute to their willingness to adopt new behaviors and cultivation techniques. With increased awareness of and

attention to their environment, it is expected that individuals become more proactive in responding to environmental degradation and more willing to collaborate with government environmental policy or decision-making or to participate in various conservation efforts.

## Conclusion

We used a triangulating framework with three approaches: perception interviews, LULC maps, and policy map, to gain unique insights on land-use change. Each of these approaches contributes to a holistic overview. The interviews provide the context of our respondents' perceived changes. The LULC maps, based on remote sensing technology, provide comprehensive data on overall land-use changes, and the policy map allows an understanding of government perceptions of development and future of land-use of the study areas. The holistic result reached through the understanding of the entirety of the structure between the social phenomenon of the local perceptions complemented by the reality of existing LULC from remote sensing data, can then be analyzed for policy implications in spatial plans.

We conclude that the local communities in our study sites are generally aware of the changes related to infrastructure development, but their awareness and perceptions of changes in natural resources is relatively low. In this regard, remote sensing data could complement local perceptions and help stakeholders to an accurate understanding of trends of ecosystem changes. Based on the environmental cognition theory of Meyfroidt (2013), our study emphasizes the importance of local perceptions of land-use changes, and how recognition of impacts of land-use changes are to a large extent determined by impacts they have on local livelihoods, such as in the case of abrasion in Derawan Island. Future research should consider the important role local knowledge and perceptions can have in the development of strategies for sustainable environmental management.

Our results from this study can be integrated into broader approaches to ecosystem conservation, targeting vulnerable areas that undergo land-use changes while at the same time providing government environmental planners with insights on the appropriateness of spatial plan policy and potential threats to the ecosystem. Combining community initiatives with effective law enforcement may spur improvement of land-use management and avoid negative impacts in the future.

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## Declarations

**Informed consent** The authors obtained informed consent from respondents to implement the survey to analyze the answers from the respondents and to write the paper which was submitted to the journal, *Human Ecology*.

**Conflict of Interest** The authors declare no conflict of interest.

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