Available online at
https://journal.rescollacomm.com/index.php/ijrcs/index

International Journal of Research in Community Service

e-ISSN: 2746-3281
p-ISSN: 2746-3273

Vol. 6, No. 2, pp. 59-71, 2025

Land Cover Changes of Pangandaran: Revealing the Tourism Attraction Impact on Coastal Urban Expansion

Umar Abdurrahman[1*], Zahara Sitta Iskandar[2], Subiyanto[1], Ismail Maqbul[1], Dining Nika Alina[1], Mochamad Rudyansyah Ismail[1]

[1] *Marine Science Department, Universitas Padjadjaran, Sumedang 45363 Indonesia*
[2] *Geography Department, Universitas Pendidikan Indonesia, Bandung 40154 Indonesia*

**Corresponding author email: u.abdurrahman@unpad.ac.id*

Abstract

As one of the main coastal tourism destinations in West Java, Pangandaran receives more than 3.5 million tourists annually, which puts significant pressure on the coastal environment. Using land cover data from 2017–2023 analyzed through regression and GIS approaches, this study identifies spatial and temporal patterns of urban expansion and their implications for environmental sustainability. The results show that urban expansion in Pangandaran is concentrated in the coastal lowlands, especially in Pangandaran and Sidamulih Sub-districts. All sub-districts in Pangandaran Regency experienced urban expansion exceeding 300 ha, with hotspots in Cimerak up to 800 ha. This urban expansion is triggered by the need for tourism infrastructure that often disregards natural ecosystems such as mangroves and coastal forests. The geographic clustering of tourist attractions in Pangandaran and Parigi continues to drive urban expansion along the coastal areas. In Cimerak and Parigi, changes are more influenced by industrial and agricultural development. In Cijulang, karst topography influences and limits the spread of urban expansion, while in Kalipucang, land cover change is limited by geographical conditions. Overall, land cover changes in the Pangandaran Sub-district coastal area are influenced by the spatial distribution of tourism attractions, geographical and geological conditions, and the characteristics of each sub-district's industrial activities. The results of this study provide important insights for policymakers to balance tourism-based development with environmental resilience in the coastal area of Pangandaran.

Keywords: Pangandaran, Land Cover Change, Coastal Urban Expansion, Tourism Impact, Sustainable Coastal Management

1. Introduction

Based on statistical data from West Java Province, the number of tourists visiting the Pangandaran area exceeds 3.5 million annually. This figure places Pangandaran as an administrative area at the Regency/City level, with the third highest number of tourist visits in West Java province. This number of tourists significantly impacts environmental dynamics, particularly in a coastal area with high anthropogenic pressure. In comparison, the number of tourists visiting Pangandaran is 7-8 times greater than the population of Pangandaran itself (BPS Jawa Barat, 2024), creating an imbalanced pressure on the environment that can potentially exceed the area's ecological capacity.

As tourist destinations, the impacts caused by tourism activities are often related to low awareness of environmental sustainability. A lack of understanding of local ecological problems, coupled with tourists' focus on recreational activities and minimal initiatives to maintain ecological conditions, often results in significant negative impacts on the ecosystem. Such behavior is also exacerbated by the desire to reduce travel costs, which reduces attention to responsible tourism practices (Eliška et al., 2023; Jun et al., 2009; Touloun & Eddali, 2023). As a result, tourist areas such as Pangandaran often face complex environmental challenges due to increasing anthropogenic pressures.

Some examples of low environmental awareness of tourists in various tourist destinations include overcrowding in sensitive areas (Ding et al., 2023; Hugo, 2020; Yu & Egger, 2021), indiscriminate littering (Labuz, 2005; Sîrbu et al., 2017), and excessive use of resources (Swarbrooke, 2020). In addition, tourist behavior can cause significant pollution. (Ji & Ding, 2024) and threaten local biodiversity (Putri & Ansari, 2023). In Pangandaran, these impacts are manifested in the ongoing land cover changes, which reflect the physical transformation of coastal areas and indicate environmental pressures that need to be addressed immediately.

On the other hand, social dynamics in Pangandaran also put pressure on the environment and regional development patterns. Urbanization of the locals to big cities such as Bandung, Bekasi, and Karawang is becoming increasingly common. The main factor driving this migration is the limited job opportunities in Pangandaran. Data from AK1 or Job Seeker Card shows that around 2,000–3,000 residents are looking for work yearly, with 80% working outside the Pangandaran area. The majority of school graduates in Pangandaran also tend to choose to leave their hometowns in order to pursue better job opportunities. This condition is exacerbated by the lack of large industries in Pangandaran that can absorb a significant number of workers, while local Micro, Small, and Medium Enterprises (MSMEs) cannot compete with large investors from outside Pangandaran (Arifin, 2023; Fadilah, 2021; Kantor Berita RMOLJABAR, 2019; Maarif, 2021a, 2021b).

This migration phenomenon poses a risk to the sustainability of development in Pangandaran. When residents leave the area, residents are less likely to be involved in the development process, while the land and resources left behind are often subject to uncontrolled exploitation. The lack of local involvement also makes environmental management more difficult, especially in the face of tourism pressures and unplanned urban expansion. In this context, collaboration between local communities, government, and the private sector is crucial to ensure that development in Pangandaran is economically profitable and environmentally sustainable.

Environmental changes in the Pangandaran coast due to tourism activities are becoming an increasingly complex issue, especially related to changes in land cover and use. The intensification of tourism sector development has led to the conversion of forest land into tourism areas (Octavianti & Agustin, 2019) and agricultural land (Nurfaizah et al., 2023). This transformation reduces the existence of natural ecosystems and increases the area's vulnerability to disasters. One clear evidence is the significant impact of the Pangandaran Tsunami in 2006, which showed the vulnerability of this area due to the loss of natural land cover and the lack of disaster-resistant infrastructure. The buildings that existed at that time mainly were not designed to withstand the force of the tsunami (Reese et al., 2007), while spatial planning did not fully consider adequate evacuation and safety routes (Harahap et al., 2023; Nurwatik et al., 2022).

This vulnerability is further exacerbated by the loss of natural barriers such as coastal forests, which are often converted to non-natural land (Lavigne et al., 2007; Tejakusuma, 2008). In fact, for example, coastal forests such as those in the Pananjung Nature Reserve, Pangandaran, have been shown to reduce the impact of tsunamis by more than 40% (Susanto et al., 2019). With predictions that Pangandaran will experience the most significant land cover change in West Java by 2030 (Virtriana et al., 2025), the urgency to manage tourism development sustainably becomes increasingly important. Protecting and restoring coastal ecosystems must be integral to regional development strategies to minimize negative environmental and societal impacts.

Considering the importance of assessing land cover changes in Pangandaran, especially those driven by tourism development, this study is designed to explore and identify the dynamics of land cover changes in the area, focusing on the relationship between tourism and land cover changes. This approach is important because land cover changes reflect the urban expansion process and affect coastal areas' vulnerability to natural disasters, as shown by various previous studies. By exploring the relationship between tourism development and physical environmental transformation, this study is expected to support more sustainable coastal area management that is adaptive to environmental and social challenges arising from these changes.

2. Materials and Methods

2.1. Study Area

Pangandaran is a coastal area with diverse ecosystems, including white sand beaches, coral reefs, mangrove forests, and tropical rainforests. Geographically, Pangandaran has coordinates between 108°30' - 108°48' East Longitude and 7°41' - 7°56' South Latitude. This area is bordered by the Ciamis Regency to the north, the Indian Ocean to the south, the Cilacap Regency to the east, and Tasikmalaya Regency to the west. With an area of around 1,011.04 km², Pangandaran has a varied topography, covering lowlands along the coastline to hills in the interior. Climatologically, Pangandaran has a tropical climate with two main seasons: the dry season (May–September) and the rainy season (October–April). Annual rainfall ranges from 2,000–4,000 mm, with an average temperature of 24–32°C. The existence of major rivers such as the Cikidang and Citanduy Rivers also plays an important role in the ecosystem and community life (BPS Kab. Pangandaran, 2024).

The study area covers the administrative area of Pangandaran Regency, with a confined focus on six of the ten sub-districts directly adjacent to the sea (Figure 1). Data from the Indonesian Topographic Map (RBI) from the Indonesian Geospatial Information Agency were used to define the study area and were used in spatial analyses. In addition, road network data from the same source were used to provide an overview of the transportation system in Pangandaran. As one of the factors influencing development, topographic data obtained from the National Digital Elevation Model (DEMNAS) by the Indonesian Geospatial Information Agency was also used to represent the geographic profile of the Pangandaran area. These data provide important information on land elevation and slope, which is relevant to analyzing land cover patterns and environmental management in this area.

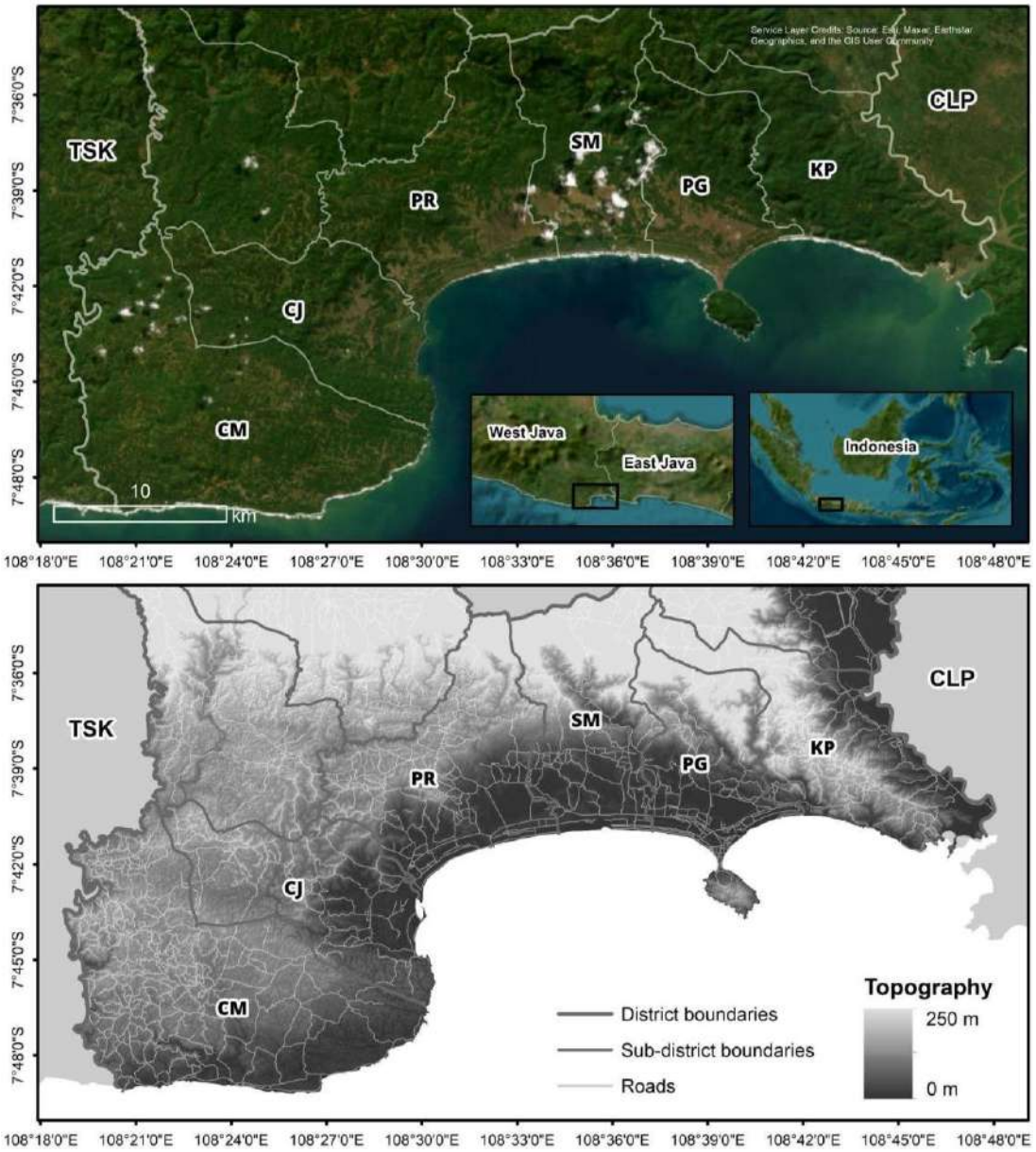

Figure 1. Map representing the study area and topography. Sub-district level: CM (Cimerak), CJ (Cijulang), PR (Parigi), SM (Sidamulih), PG (Pangandaran), KP (Kalipucang). Bordering District: TSK (Tasikmalaya), CLP (Cilacap)

2.2. Land Cover

In this study, the primary data utilized the ready-to-use land cover dataset by Karra et al. (2021) accessed through the Land Cover Explorer by Living Atlas ArcGIS platform (https://livingatlas.arcgis.com/landcoverexplorer/). This dataset provides annual basis land cover data from 2017 to 2023, all of which are used for temporal and spatial analysis in the study area. Esri launched this global land cover map in collaboration with the Impact Observatory, which announced its update on April 30, 2024. This map is based on Sentinel-2 satellite data with a resolution of 10 meters and machine learning workflows in its processing, provided by the European Space Agency (ESA) and hosted on Microsoft Planetary Computer.

The dataset classifies land cover into nine main classes: Water (areas dominated by water throughout the year, such as rivers, lakes, and seas), Trees (tall vegetation with dense canopies such as forests and mangroves), Flooded Vegetation (frequently flooded vegetation such as rice fields and wetlands), Crops (agricultural lands such as corn and wheat), Built-up Area (area with an artificial structure such as buildings and roads), Bare Ground (area without vegetation such as deserts and mines), Snow/Ice (areas with permanent snow or ice, but was not found in the study area), Clouds (an area with persistent cloud cover), and Rangeland (natural grassland or savanna with low vegetation).

The land cover map obtained for the Pangandaran Regency area was then clipped so that it only covers sub-districts directly adjacent to the sea. Furthermore, a merge process was carried out on the land cover class, so the dataset used

in this study consists of five main classes: Built-up Area, Bare Ground, Crops, Flooded Vegetation and Rangeland, and Trees. The results of this processing provide a more specific and relevant picture of the characteristics of the study area. The land cover map resulting from the processing is shown in Figure 2 as a spatial representation of the study area.

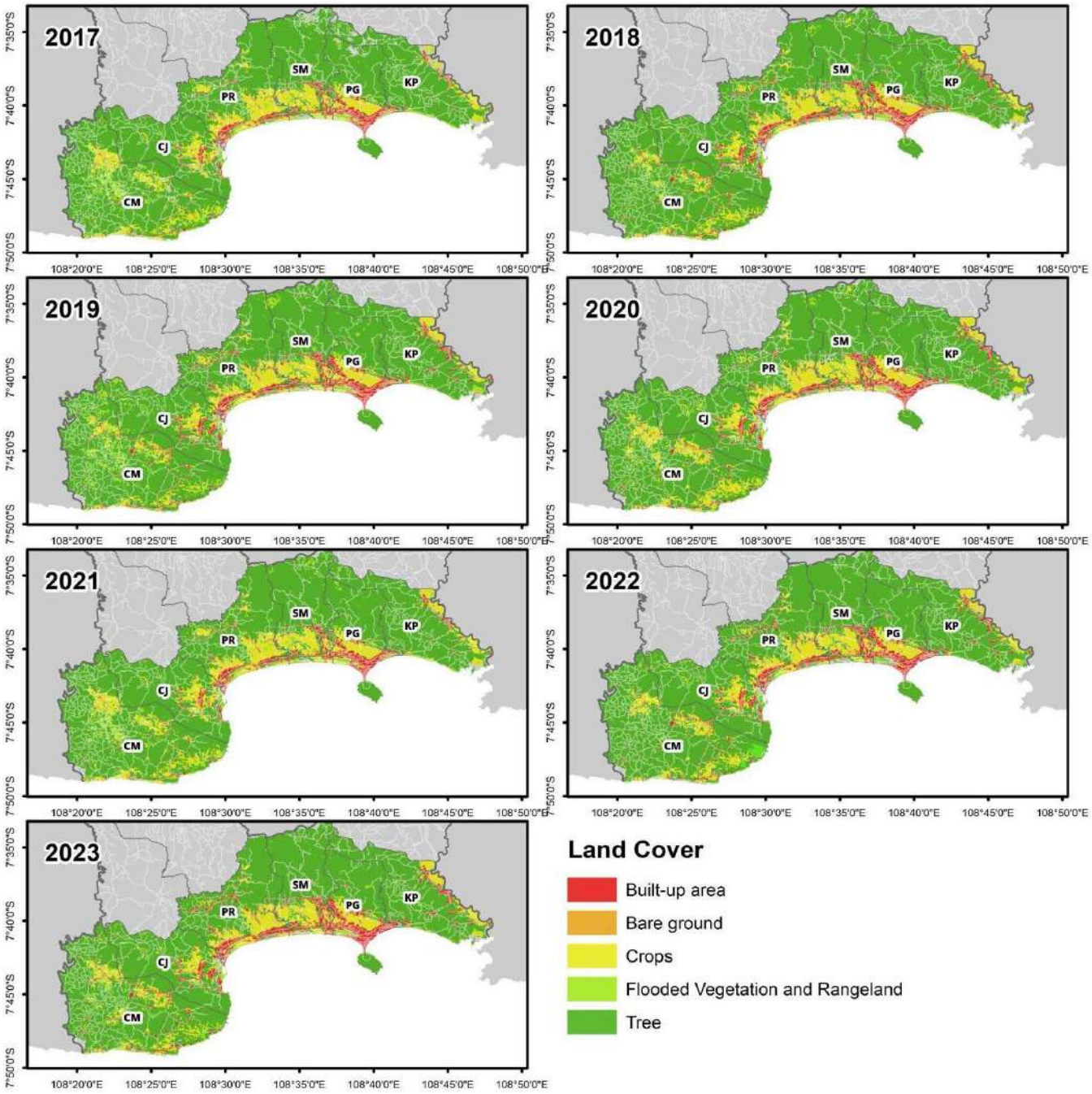

Figure 2. Land cover in Pangandaran during the period 2017–2023

Using this land cover data makes it possible to analyze changes in land cover over time and provide in-depth information about the dynamics in the study area. This dataset is integrated with a GIS system to support more detailed geospatial analysis, including overlays with administrative data, road networks, and topographic data relevant to the research objectives.

2.3. Land Cover Change Rates

Land cover change analysis can be done using various techniques (MohanRajan et al., 2020). This study uses a linear regression calculation with a slope value representing the land cover change rate. The calculation was performed using the raster calculator tool for all land cover data considered in this study. The year (x) was reclassified into a numeric value, namely 2017 as Class 1, 2018 as Class 2, 2019 as Class 3, 2020 as Class 4, 2021 as Class 5, 2022 as Class 6, and 2023 as Class 7, to allow linear temporal analysis. Land cover classes (y) were also reclassified, with Built-up Area as

Class 1, Bare Ground as Class 2, Crops as Class 3, Flooded Vegetation and Rangeland as Class 5, and Trees as Class 6. The analysis was performed with a total of 7-time steps ($n = 7$) for the period 2017–2023.

$$m = \frac{n \cdot \sum(x \cdot y) - \sum x \cdot \sum y}{n \cdot \sum x^2 - (\sum x)^2}$$

A negative slope indicates a downward trend, such as converting vegetation into built-up areas, hereinafter referred to as urban expansion. A positive slope indicates an upward trend, such as converting built-up areas into vegetation, hereinafter referred to as urban decline. A slope value approaching zero indicates stability without significant change. This method identifies the dynamics of land cover change, both urban area change trends and land use stability in the study area. The land cover change rate calculation results are then plotted on a map.

3. Results and Analysis

3.1. Tourism Hotspot in the Pangandaran Coastal Area

In supporting the land cover change analysis, plotting of tourism attraction locations along the Pangandaran coastal area was also carried out. Data on these tourist attractions were obtained from Google Maps specified to the Attractions category, a spatial data utilization technique similar to that used by (Huang, 2022). The information collected includes the location's name, the number of reviews, and the coordinates of each tourist attraction. Sixty-two tourist attractions in the Pangandaran area are listed on Google Maps. Table 1 shows the 10 tourist attractions with the most reviews along the Pangandaran coastal area. The tourist attraction with the most reviews is in the main area of Pangandaran Beach (Table 1, Code A), with more than 20,000 reviews. Meanwhile, other tourist attractions, such as Pangandaran Sunset Park (Code B) and Green Canyon Pangandaran (Code C), are the second and third most reviewed tourist attractions. The main area of Pangandaran beach showed a much higher intensity of visits compared to other tourist attractions in the Pangandaran coastal area. In addition to beach attractions, other attractions, such as the town square, are popular tourist destinations in the coastal area of Pangandaran. There is also a special interest in tourism, such as Green Canyon Pangandaran and Batu Karas Surf Spot, adding variety to tourism segments in the Pangandaran area.

Table 1. Top 10 Tourist Destinations with Highest Review Counts in Pangandaran

Code	Name of Tourism Area	Number of Reviews
A	Main area of Pangandaran Beach, covering: - Pangandaran East Coast - Pangandaran West Coast - Pangandaran Beach - Pangandaran White Sand Beach - Pangandaran Nature Reserve	>20,000 in total
B	Pangandaran Sunset Park	8,129
C	Green Canyon Pangandaran	8,087
D	Madasari Beach	6,691
E	Karapyak White Sand Beach	4,384
F	Batu Karas Surf Spot	2,874
G	Batu Hiu Beach	2,161
H	Citumang Body Rafting	2,066
I	Aquarium Pangandaran Indonesia	1,691
J	Parigi Square	1,100

The review data is then plotted spatially onto a map of the study area, with the size of the symbol representing the number of reviews as an indicator of popularity and also assumed to represent the intensity of visits (Figure 3). The determination of the size of this symbol aims to provide a visual depiction of the distribution and intensity of tourism

activities along the Pangandaran coast. Based on the plotting results, the intensity of tourism activities in the Pangandaran coastal area tends to be concentrated along the coastline, with maritime/marine tourism activities. According to (Orams & Lück, 2014), marine tourism is a recreational activity focusing on utilizing the marine environment as a location for tourism activities, including the marine environment as a tourist attraction. In addition to marine tourism, several activities are far from the coastline and have a reasonably high intensity, namely the Green Canyon (C) and Citumang Body Rafting (H). In addition to natural tourism, artificial attractions have a relatively high intensity of tourism activities compared to other tourist attractions, namely Aquarium Pangandaran Indonesia (I) and Parigi Square (J). Pangandaran Indonesia Aquarium, or Pangandaran Integrated Aquarium and Marine Research Institute (PIAMARI) as its official name, was opened in late 2022, and it serves tourism, education, and conservation hubs simultaneously. Classified as a newly built facility, Pangandaran Indonesia Aquarium has become popular because it offers an aquarium tourism experience distinguished from other traditional tourist attractions in Pangandaran (Prasetiawan et al., 2023). Parigi Square is also one of the most visited artificial tourist attractions, especially for the locals. The reason is that the Parigi Sub-district is the center of government for the Pangandaran Regency. At the same time, its town square is the center of community social activities, green open space, and easy access to the city center. Parigi Square also has historical value and the identity of the Pangandaran Regency.

Spatially, the number of tourism activities in Cimerak Sub-district, the western part of the Pangandaran coast, tends to be fewer than in other areas. In fact, Cimerak is the largest sub-district with the longest coastline compared to other sub-districts along the coast of Pangandaran Regency. Referring to the Pangandaran Regency Spatial Plan document for 2018-2038, tourism activities in this sub-district are still minimal. However, the Cimerak Sub-district is directed as an agro-industrial area and a new tourism development area. Meanwhile, high-intensity tourism activities are found in the eastern part of the Pangandaran coast, which includes Kalipucang Sub-district, Pangandaran Sub-district, and Sidamulih Sub-district. In addition, based on the spatial planning policy, the three sub-districts are indeed directed as the leading national and international tourism areas.

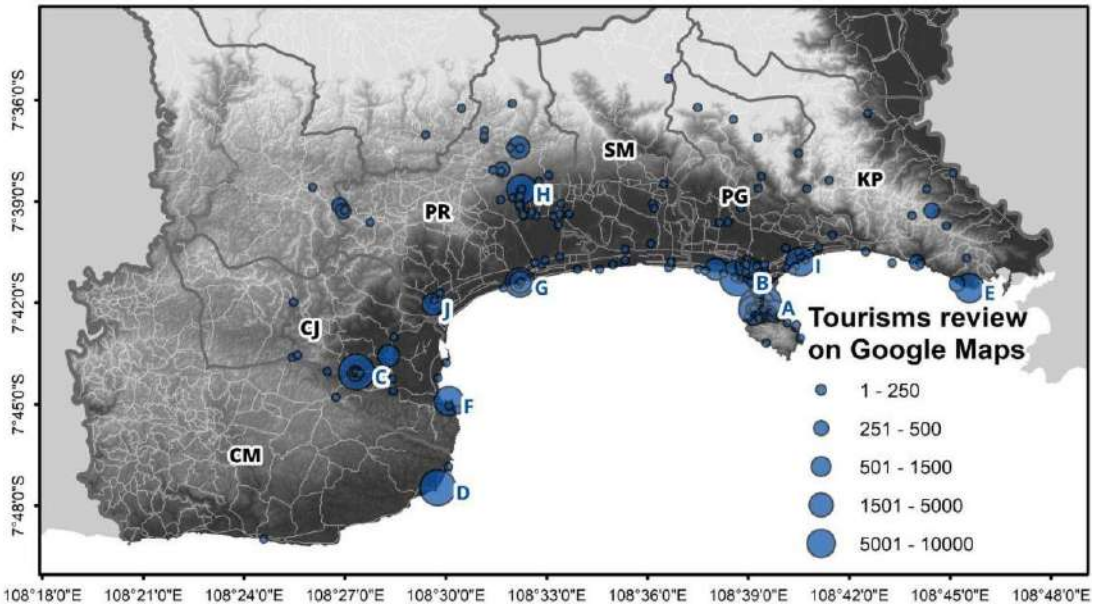

Figure 3. Distribution of tourism attractions in Pangandaran

3.2. Land cover change rates in Pangandaran Coastal Area

The regression approach is applied to analyze land cover changes to identify the trends and patterns from 2017 to 2023. This study used tools that allow for calculating annual land cover data from that period, which are then calculated quantitatively for the slope in the regression approach. The results of this calculation are then plotted to provide a spatial visualization that shows the spatial distribution of urban expansion and urban decline, and no significant change is displayed in Figure 4.

Based on the distribution of land cover changes in the coastal area of Pangandaran, there are several characteristics of the distribution of land cover changes. Land cover changes in the Cimerak Sub-district tend to cover the entire area, indicating that the development process occurred in the same coverage. Meanwhile, land cover changes in Sidamulih and Pangandaran Sub-districts tend to occur along the coastline, indicating an increase in development along this area. In contrast to the Sidamulih and Pangandaran Sub-districts, land cover changes in the Parigi Sub-district occur away from the coastline. This shows an increase in the intensity of regional development away from the coastline. In the eastern part, land cover changes often occur in the border area between Pangandaran Regency and Cilacap Regency.

This shows that development activities on the east coast of Pangandaran Regency tend to be influenced by Cilacap Regency, and vice versa.

Based on topography, land cover changes mainly occur in the lowlands marked by darker-colored areas in Figure 4. Topographic conditions are considered to influence significantly the distribution of land cover changes that occurred in the whole coastal area of Pangandaran. In addition, distinctive areas that do not show significant land cover changes are found between Pangandaran and Kalipucang Sub-districts and between Cimerak and Cijulang Sub-districts. The absence of land cover change in these areas is due to the area consisting of karst topography, which is composed of soluble rocks such as limestone and dolomite forming its geological profile (Scheffers et al., 2015). Karst topography is a valuable natural landscape for geo-tourism attraction, but on the other hand, it limits urban expansion because it is less favorable for industrial and housing construction, as well as agricultural activities (Hindersah et al., 2020; Nia et al., 2020).

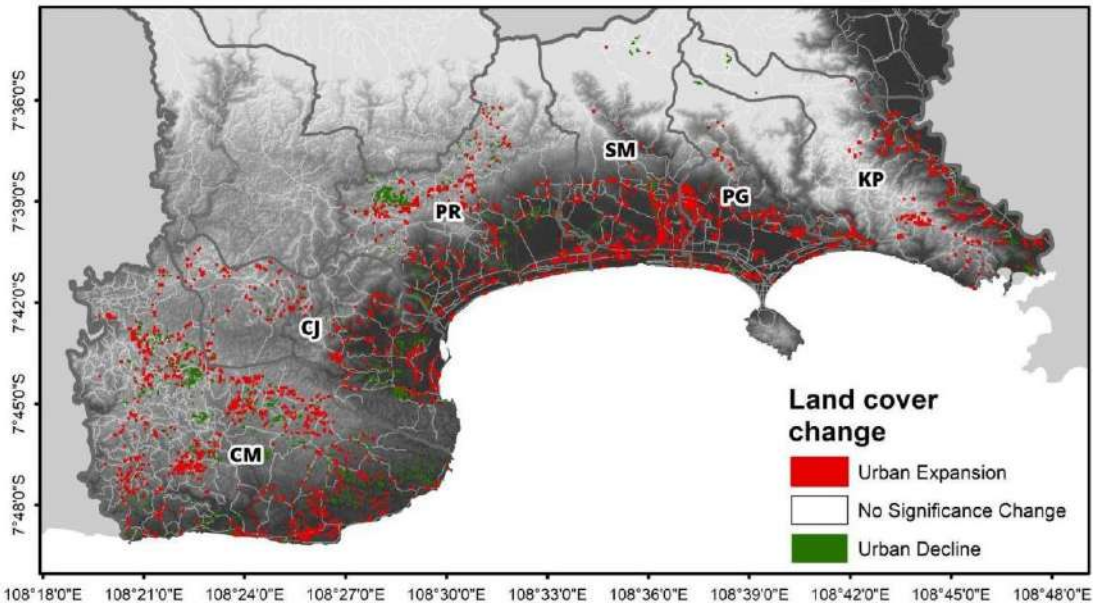

Figure 4. Land cover change in Pangandaran

The distribution graph of land cover changes divided by administrative area shows the number of land cover changes, both in the form of urban expansion, no significant change, and urban decline, in each sub-district in Pangandaran. This graph aims to provide a clearer picture of the proportion of each category of land cover changes so that it can identify patterns of change that occur in various administrative areas.

Cimerak Sub-district is a hotspot for land cover change along the coast of Pangandaran, with a total land cover change area of 851.3 ha. This is expected to have occurred due to increased community activity in the Cimerak Sub-district, driven by the direction of spatial development in the district as a new tourism development area in Pangandaran Regency. Land cover changes in Cimerak occurred because most of its land cover area was in the form of crops, which allowed for alternating cycles of crops (vegetation) and bare ground land cover. The land cover in the form of built-up, especially the red dots that stand out, are large industries. Urban expansion was detected, especially around large industrial areas, indicating development to support the industry. These industries were detected in 2018-2020 and 2022-2023, while in 2017 and 2021, this land cover disappeared. The undetectability of these industries at a certain time indicates the shortcomings of this study, which relies on ready-to-use data from Sentinel-2 Land Cover Explorer by Esri.

Analysis of land cover change distribution shows that Parigi Sub-district is the second hotspot for land cover change, both in the form of urban expansion and urban decline. Urban decline hotspots in Parigi mainly occur in agricultural areas detected as crops, indicating the potential for alternating two-way land cover changes. On the other hand, significant urban expansion in Parigi also comes from land cover changes around the crops, significantly contributing to the region's high urban expansion.

The next most significant urban expansion after Parigi occurred in Cimerak, with the primary source of land cover change coming from around the crops. In Pangandaran Sub-district, urban expansion is still driven by infrastructure development that supports tourism. Meanwhile, in Kalipucang, urban expansion occurred due to development that directly borders Cilacap Regency. Sidamulih developed as a supporting area for Pangandaran, while development in Cijulang was mainly influenced by coastal tourism. Urban decline or land cover change from built-up to vegetation is less common. However, in some cases, it can occur due to agricultural expansion and the effort to return natural environmental conditions through restoration projects, policy interventions, and community initiatives (Alijani et al.,

2020; Liu et al., 2022). However, this case is unlikely to occur in Pangandaran, leaving seasonal crops changes as the expected cause of the detected urban decline.

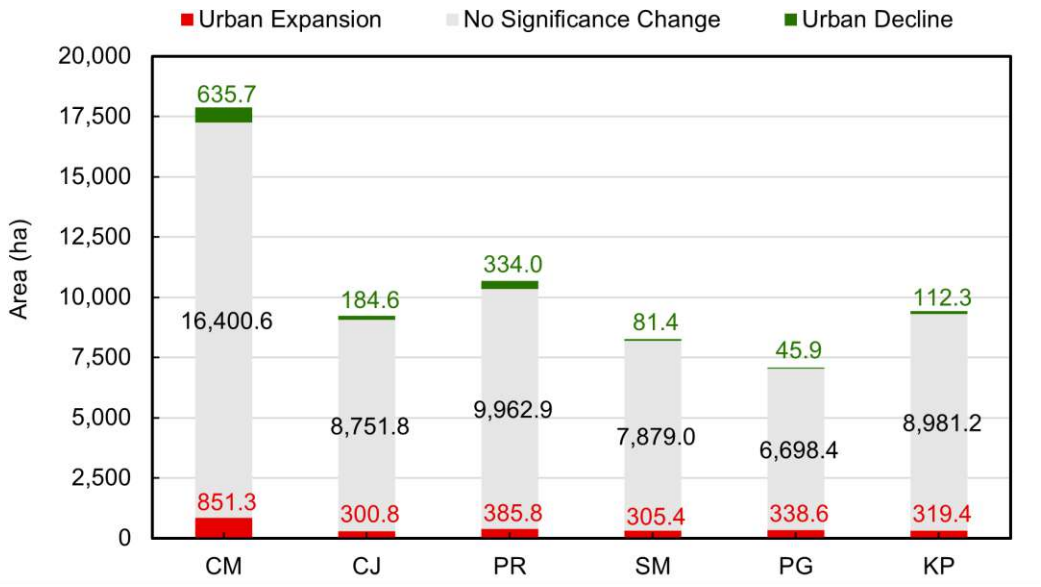

Figure 5. The chart represents the distribution of land cover change based on administrative areas

Overall, all sub-districts in Pangandaran show urban expansion exceeding 300 hectares, with the primary sources coming from agro-industrial areas, industrial establishment, tourism development in the main and supporting areas, and development in areas bordering other areas. On the other hand, urban decline occurs in crops, which can cause bias in the analysis due to land cover fluctuations and potential two-way changes in the crops.

3.3. Between Tourism Hotspot and Land Cover Change Rates

Land cover change analysis shows that urban expansion triggered by coastal tourism occurred significantly in the Pangandaran Sub-district and spread to the Sidamulih Sub-district. Pangandaran Sub-district remained the main driver of urban expansion during the observation period, with urban expansion hotspots visible in this area. This expansion was not only limited to the center of the Pangandaran Sub-district but also spread to surrounding areas, such as Sidamulih, indicating a pattern of regional development that supports coastal tourism activities. Tourism catalyzes urban development in the tourism area and the surrounding areas as a supporting area. This has also occurred in several other areas, such as Bali (Rimba et al., 2020), Jakarta (Krisnadi et al., 2022), and Bandung (Hermawan et al., 2018).

Despite the dominant urban expansion, the Pangandaran Nature Reserve area remains intact, without any significant land cover changes, indicating the success of the conservation of this conservation area. Interestingly, urban expansion in the Pangandaran Sub-district is not located directly in the main tourist attraction hotspots because the area has long been developed. Instead, urban expansion is expanding into previously undeveloped areas, indicating a pattern of new development distribution to meet the needs of supporting tourism and urban expansion in this area. This highlights the relationship between coastal tourism and urban expansion dynamics, with important implications for sustainable coastal development management.

The Kalipucang area, located in the easternmost part of Pangandaran Regency, shows different urban area change dynamics compared to other areas. Although urban expansion from Cilacap Regency, which directly borders Kalipucang, impacts changes in land cover in the area, this influence is not significant. This is mainly due to the geographical conditions and hilly contours of the Kalipucang area, which naturally limit the development of urban areas.

Factors such as limited accessibility, topographic challenges, and limited infrastructure are the main barriers to large-scale urban expansion in Kalipucang. As a result, the area maintains its relatively natural characteristics with minimal land cover changes during the observation period. This analysis underlines the impact of geographical conditions as a limiting factor in the urban expansion process in the coastal areas of Pangandaran Regency. Different urban area change dynamics indicate the presence of buffer zones, such as Cimerak and Cijulang Sub-districts. Urban expansion in Cimerak Sub-district is thought to be more influenced by the presence of industrialization, including factories in the surrounding area, than by tourism activities. On the other hand, although there are tourist attractions in Cijulang Sub-district, such as Green Canyon, urban expansion in this area has not occurred as massively as in Pangandaran Sub-

district. This is likely due to the limited land capacity in Cijulang, including its geological profile dominated by karst areas, which are less than ideal for urban development (Liszkowski, 1975; Vierrether, 2013).

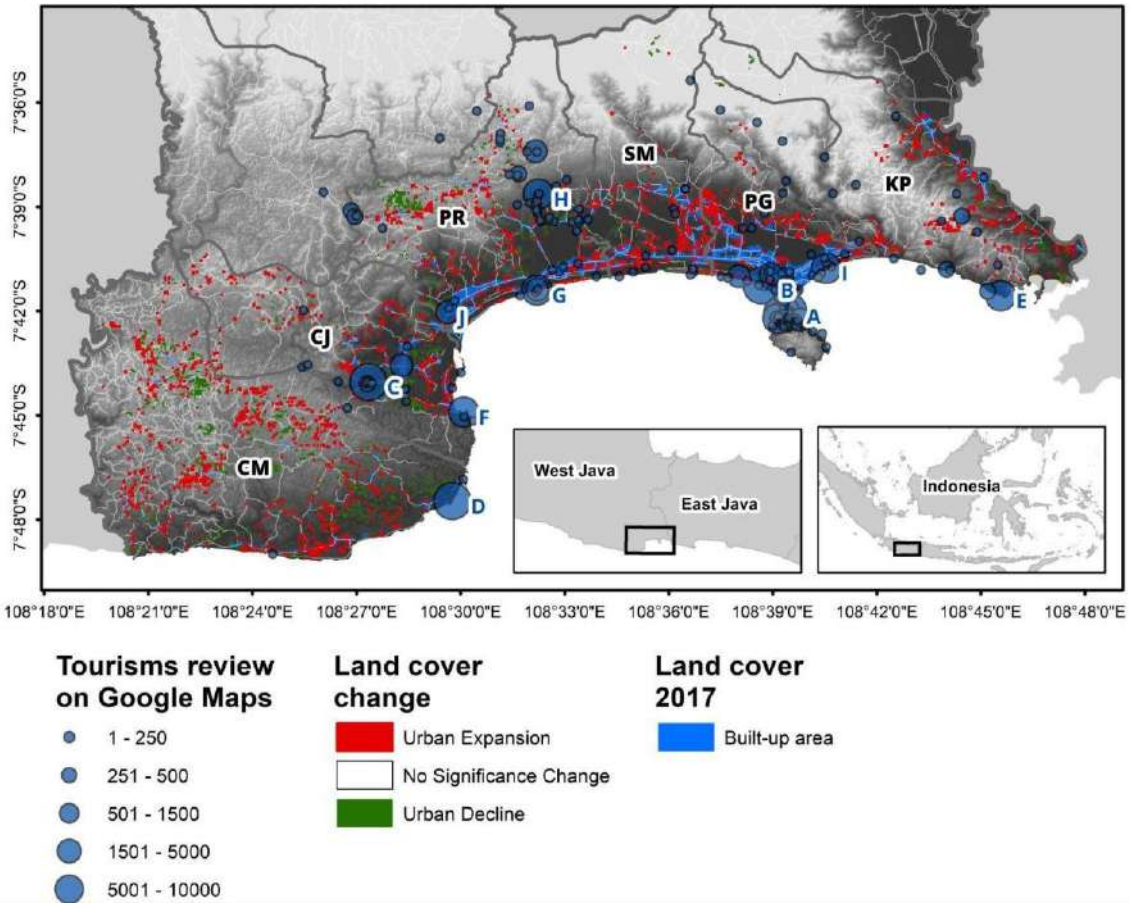

Figure 5. Tourism attraction and land cover change rate

Urban expansion that was expected to occur in Cijulang appears to have shifted to the Cimerak area. A combination of karst-based tourism and the presence of industrial facilities drives urban expansion in Cimerak. This pattern reflects the complex relationship between land characteristics, tourism activities, and the influence of industrialization on land cover change, with important implications for development management in the Pangandaran tourism buffer zone.

Parigi and Cijulang Sub-districts are experiencing urban expansion driven by factors other than coastal tourism, namely special interest tourism based on the uniqueness of natural formations, such as Green Canyon and river-based tourist attractions. This area has become a tourist destination that attracts attention because of its unique natural beauty, thus triggering supporting infrastructure development, such as accommodation, restaurants, and transportation facilities. Urban expansion in these two districts highlights the significant influence of special interest tourism on land cover change, especially in areas around natural tourist attractions. This development pattern differs from that of coastal areas because it focuses more on development that follows the natural attractions of rivers and valleys. These dynamics provide an overview of the variety of factors driving urban expansion in the Pangandaran area, which is not only influenced by coastal tourism but also by the unique potential of ecotourism and nature-based tourism.

4. DISCUSSION

Urban expansion in Pangandaran, Sidamulih, Cijulang, and Cimerak areas indicates increased coastal vulnerability, mainly due to development concentrated near the coastline. This condition poses a significant risk, considering that low-lying coastal areas are vulnerable to natural disasters, such as tsunamis, as mentioned by Lavigne et al. (2007) and Tejakusuma (2008). This expansion is triggered by tourism activities that encourage the conversion of natural land into built-up areas without considering the protection of buffer ecosystems, such as coastal forests and mangroves. The loss of these natural barriers further increases the risk of disasters and is detrimental to the environmental sustainability of coastal areas. Therefore, a more sustainable development planning approach is needed, considering disaster risk management and coastal ecosystem preservation to support environmental carrying capacity and community safety in the Pangandaran area.

In addition to the aspect of tourism attraction, changes in land cover in Pangandaran are also influenced by physical geographical constraints, which are the main factors driving land use dynamics. The topography of the area, dominated by low coastal areas and karst hills, creates a development pattern that focuses on lowlands that are more easily accessible. Areas such as Pangandaran and Sidamulih, with good accessibility, have become the main development centers. In contrast, areas with hilly topography, such as Cijulang and Kalipucang, experience limited urban expansion due to less supportive geographical conditions. These physical constraints also affect the intensity of infrastructure development, where areas with steep slopes and karst geological characteristics are more difficult to develop for residential or commercial areas. Thus, geographical factors play an important role in shaping land cover change patterns in Pangandaran, in addition to the strong push from tourism activities.

If these land cover changes continue and are only concentrated in the lowlands, the Pangandaran area has the potential to reach a state of built-up area saturation due to being driven by tourism (Resky, 2022; Sunarta & Saifulloh, 2022). With limited flat land that can be developed, intensification of development in this area will trigger various environmental problems, including increased risk of coastal flooding (Andreadis et al., 2022), decreased groundwater absorption capacity (Lubis et al., 2009), and degradation of coastal environmental quality (Surya et al., 2022). In addition, built-up area saturation can also reduce tourist appeal, especially if development is not accompanied by adequate spatial planning and preservation of natural ecosystems. An adaptive and sustainability-based spatial planning approach is needed to prevent these negative impacts, prioritizing land use diversification and protecting areas with important ecological functions.

Recommendations for future coastal management, especially Pangandaran Regency Spatial Planning Plan, as in Pangandaran Regency Regional Regulation Number 3 of 2018, should focus on a sustainable approach that integrates environmental protection, disaster risk reduction, and economic development needs. The present study shows that the main driver of urban expansion in Pangandaran is still the hotspot of tourist attractions, especially those based on nature and the surrounding areas that support the hotspot. In addition, regional spatial planning and industrial activities can also significantly drive urban expansion, such as in the Cimerak Sub-district. Development outside the administrative area can also trigger urban expansion, such as in Kalipucang Sub-district. The main priority of regulation should still be towards preserving and restoring coastal ecosystems, such as mangroves and coastal forests, which serve as natural barriers to disasters and have high ecological value. In addition, coastal management should be supported by adaptive spatial planning, which includes risk zoning, development restrictions in disaster-prone areas, and improvements to disaster-resistant infrastructure. Community-based approaches also need to be strengthened through local community involvement in decision-making, education on the importance of sustainability, and the development of alternative environmentally-based economic programs. With these steps, the Pangandaran coastal area can be more integrated and resilient to future environmental challenges.

5. CONCLUSION

This study shows that land cover changes in the coastal area of Pangandaran are driven by tourism activities and influenced by physical geographical constraints that limit development outside the lowlands. Intense urban expansion in coastal areas, especially in Pangandaran and Sidamulih, increases environmental pressure and disaster risks due to the loss of natural barriers such as mangroves and coastal forests. Suppose this pattern of change continues without adequate planning. In that case, the area may reach a state of built-up area saturation, which triggers various environmental problems, such as decreased water absorption capacity, increased flood risk, and degradation of coastal ecosystem quality. Therefore, an integrated and sustainability-based coastal management approach is needed, including the preservation of critical ecosystems, adaptive spatial planning, and empowerment of local communities to ensure the sustainability of development in the coastal area of Pangandaran. These findings provide an important basis for supporting sustainable coastal area management decision-making.

The results of this study also reveal variations in land cover changes in each coastal area. Pangandaran Sub-district experienced massive urban expansion with concentration along the coastline, driven by the need for supporting tourism infrastructure. Sidamulih developed as a supporting area for Pangandaran, showing a similar pattern of change but on a smaller scale. Although not directly adjacent to the sea, Parigi showed an intensification of development in areas away from the coastline, reflecting the influence of local economic activities. Cimerak became the primary hotspot for land cover change, with more complex dynamics due to the combination of industrial development and the influence of karst-based tourism. Meanwhile, Cijulang showed slower urban expansion, limited by karst topography, which is less than ideal for urban development. Unlike other areas, Kalipucang maintained its natural characteristics due to geographical constraints limiting urban expansion. The differences in these patterns of change provide valuable insights into the need for a contextual management approach according to the characteristics of each region.

References

Alijani, Z., Hosseinali, F., & Biswas, A. (2020). Spatio-temporal evolution of agricultural land use change drivers: A case study from Chalous region, Iran. *Journal of Environmental Management*, *262*. https://doi.org/10.1016/J.JENVMAN.2020.110326

Andreadis, K. M., Wing, O. E. J., Colven, E., Gleason, C. J., Bates, P. D., & Brown, C. M. (2022). Urbanizing the floodplain: global changes of imperviousness in flood-prone areas. *Environmental Research Letters*, *17*(10), 104024. https://doi.org/10.1088/1748-9326/ac9197

Arifin, S. (2023). Minim Lapangan Kerja, Tiap Tahun Sekitar 2000 Warga Pangandaran Mengadu Nasib Ke Kota Lain. *Kantor Berita RMOL JABAR*. https://www.rmoljabar.id/minim-lapangan-kerja-tiap-tahun-sekitar-2000-warga-pangandaran-mengadu-nasib-ke-kota-lain

BPS Jawa Barat. (2024). *Jumlah Kunjungan Wisatawan Ke Objek Wisata (Orang), 2021-2023*. https://jabar.bps.go.id/id/statistics-table/2/MjIwIzI=/jumlah-kunjungan-wisatawan-ke-objek-wisata.html

BPS Kab. Pangandaran. (2024). *Kabupaten Pangandaran Dalam Angka 2024*. https://pangandarankab.bps.go.id/id/publication/2024/02/28/83dfc0979c63eeecdf5fee1c/kabupaten-pangandaran-dalam-angka-2024.html

Ding, S., Zhang, R., Liu, Y., Lu, P., & Liu, M. (2023). Visitor crowding at World Heritage Sites based on tourist spatial-temporal distribution: a case study of the Master-of-Nets Garden, China. *Journal of Heritage Tourism*, *18*(5), 632–657. https://doi.org/10.1080/1743873X.2023.2214680

Eliška, F., Jannis, A., & C., R. (2023). Factors Influencing the Environmental Awareness of Visitors to the Natural Protected Areas on the Island of Tenerife. *Envigogika*. https://doi.org/10.14712/18023061.663

Fadilah, A. N. (2021, April 2). Warga Pangandaran Berpotensi Terasingkan Akibat Urbanisasi Penduduk, Akademisi: Memilih Tinggal di Kota Sumber Artikel berjudul "Warga Pangandaran Berpotensi Terasingkan Akibat Urbanisasi Penduduk, Akademisi: Memilih Tinggal di Kota", selengkapnya dengan. *News Priangan Timur*. https://priangantimurnews.pikiran-rakyat.com/news-priangan/pr-1221709700/warga-pangandaran-berpotensi-terasingkan-akibat-urbanisasi-penduduk-akademisi-memilih-tinggal-di-kota?page=all

Harahap, P., Sapanji, R. A. E. V. T., & Nugraha, U. (2023). Geographic Information System for Tsunami Disaster Mitigation Evacuation Routes Moving the Sunda Subduction Megathrust (Case Study: Analysis of Pangandaran Regency). *Journal of Applied Geospatial Information*, *7*(2), 956–963. https://jurnal.polibatam.ac.id/index.php/JAGI/article/view/6518/2109

Hermawan, P., Widiyanti, R., Mayangsari, L., & Novani, S. (2018). Urban Tourism Development for Bandung City, Indonesia: A Preliminary Study. *International Journal of Business and Society*, *19*(1), 73-.

Hindersah, R., Kurniati, N., Sukarsa, D. E., Rustam, R., & Kuswaryan, S. (2020). Sustainable food crop production in karst area of Parigi, Pangandaran, West Java: preliminary study. *Jurnal Perspektif Pembiayaan Dan Pembangunan Daerah*, *8*(1), 41–50. https://doi.org/https://doi.org/10.22437/ppd.v8i1.7599

Huang, T. (2022). *The spatial accessibility of attractive parks in Chicago and a proposed planning support system to evaluate the accessibility of POIs* [University of Illinois at Urbana-Champaign]. https://doi.org/https://doi.org/10.48550/arXiv.2212.06036

Hugo, N. C. (2020). *Overtourism at Heritage and Cultural Sites BT - Overtourism: Causes, Implications and Solutions* (H. Séraphin, T. Gladkikh, & T. Vo Thanh (eds.); pp. 169–185). Springer International Publishing. https://doi.org/10.1007/978-3-030-42458-9_10

Ji, X., & Ding, X. (2024). Analysis on the relationship between coastal tourism and marine pollution: an empirical analysis of China's 11 coastal regions. *Frontiers in Marine Science*, *11*. https://doi.org/10.3389/fmars.2024.1471467

Jun, L., Tian, C., & Li-mei, L. (2009). An investigation and analysis of tourists' environmental consciousness. *Geographical Research*, *28*(1), 259–270. https://doi.org/10.11821/yj2009010027

Kantor Berita RMOLJABAR. (2019). Ribuan Calon Pekerja Asal Pangandaran Bakal Ramaikan Urbanisasi. *Kantor Berita RMOL JABAR*. https://www.rmoljabar.id/ribuan-calon-pekerja-asal-pangandaran-bakal-ramaikan-urbanisasi

Karra, K., Kontgis, C., Statman-Weil, Z., Mazzariello, J. C., Mathis, M., & Brumby, S. P. (2021). Global land use / land cover with Sentinel 2 and deep learning. *IEEE International Geoscience and Remote Sensing Symposium IGARSS, Brussels, Belgium, 2021*, 4704–4707. https://doi.org/10.1109/IGARSS47720.2021.9553499

Krisnadi, A. R., Djati, S. P., Nurbaeti, N., & Wulan, S. (2022). Identification of Urban Areas As Urban Tourism Destinations in the Special Capital Region of Jakarta. *INTERNATIONAL CONFERENCE ON RESEARCH AND DEVELOPMENT (ICORAD)*, *1*(2), 188–204. https://doi.org/10.47841/icorad.v1i2.34

Labuz, T. (2005, January 1). Tourists ecological awareness-key to understanding human behaviour in coastal environment. *Proceedings 'Dunes and Estuaries 2005' - International Conference on Nature Restoration Practices in European Coastal Habitats, Koksijde, Belgium, 19-23 September 2005*.

Lavigne, F., Gomez, C., Giffo, M., Wassmer, P., Hoebreck, C., Mardiatno, D., Prioyono, J., & Paris, R. (2007). Field

observations of the 17 July 2006 Tsunami in Java. *Natural Hazards and Earth System Sciences*, *7*(1), 177–183. https://doi.org/10.5194/nhess-7-177-2007

Liszkowski, J. (1975). The influence of karst on geological environment in regional and urban planning. *Bulletin of the International Association of Engineering Geology*, *12*(1), 49–51. https://doi.org/10.1007/BF02635428

Liu, Y. L., Liu, S., Wu, M., Tian, X.-L., & Liu, S. (2022). *Effect of Land Use/Land Cover Change on the Concentration of Se and Heavy Metals in Soils from a "Return Cropland to Forest" Area, Southwest China*. *43*(6), 3262–3268. https://doi.org/10.13227/j.hjkx.202109035

Lubis, R. F., Yamano, M., Delinom, R. M., Sudaryanto, Sakura, Y., Goto, S., Miyakosh, A., & Taniguchi, M. (2009). Urban groundwater loading in Indonesian mega-cities. *IAHS-AISH Publication*, 291–298. https://www.cabdirect.org/cabdirect/abstract/20103145239

Maarif, S. (2021a). Pangandaran Terancam Kehilangan Penduduk Pribumi, Arus Urbanisasi harus Diputus. *INews Jabar*. https://jabar.inews.id/berita/pangandaran-terancam-kehilangan-penduduk-pribumi-arus-urbanisasi-harus-diputus

Maarif, S. (2021b, April 1). UMKM Pangandaran Harus Mampu Menekan Angka Urbanisasi. *Times Indonesia*. https://timesindonesia.co.id/ekonomi/338338/umkm-pangandaran-harus-mampu-menekan-angka-urbanisasi

MohanRajan, S. N., Loganathan, A., & Manoharan, P. (2020). Survey on Land Use/Land Cover (LU/LC) change analysis in remote sensing and GIS environment: Techniques and Challenges. *Environmental Science and Pollution Research*, *27*(24), 29900–29926. https://doi.org/10.1007/s11356-020-09091-7

Nia, K., Reginawanti, H., & Dadang, Epi, S. (2020). Legal aspect of green geotourism development of the karst area in Pangandaran: synchronization between the regulation and the living law. *Environmental Policy and Law*, *50*(1–2), 103–110. https://doi.org/https://doi.org/10.3233/EPL-200200

Nurfaizah, D., Pravitasari, A. E., Lubis, I., & Saizen, I. (2023). Land cover changes and spatial planning alignment in East Java Province. *IOP Conference Series: Earth and Environmental Science*, *1133*(1), 12049. https://doi.org/10.1088/1755-1315/1133/1/012049

Nurwatik, N., Bioresita, F., & Setiawan, D. A. (2022). Penentuan Lokasi Titik Evakuasi Sementara Bencana Tsunami Menggunakan Metode Network Analyst (Studi Kasus: Pesisir Selatan Kabupaten Pangandaran). *Geoid*. https://api.semanticscholar.org/CorpusID:245955149

Octavianti, M., & Agustin, H. (2019). The Perception of Local People on Forest Conversion. *Proceedings of 1st Workshop on Environmental Science, Society, and Technology, WESTECH 2018*. https://doi.org/10.4108/eai.8-12-2018.2283962

Orams, M. B., & Lück, M. (2014). Coastal and Marine Tourism. In *The Wiley Blackwell Companion to Tourism* (pp. 479–489). https://doi.org/https://doi.org/10.1002/9781118474648.ch38

Prasetiawan, N. R., Kurniasih, R. A., Ma'muri, Setiawan, A., Bramawanto, R., Mulyadi, U., & Nugraha, A. (2023). *Life support systems and aquatic communities in public aquariums*. *1221*. https://doi.org/10.1088/1755-1315/1221/1/012021

Putri, I. A. S. L. P., & Ansari, F. (2023). Visitors' Awareness to Maintain and Preserve the Biodiversity and Environment at Bantimurung Nature Tourism Object, Bantimurung Bulusaraung National Park. *IOP Conference Series: Earth and Environmental Science*, *1181*(1), 12005. https://doi.org/10.1088/1755-1315/1181/1/012005

Reese, S., Cousins, W. J., Power, W. L., Palmer, N. G., Tejakusuma, I. G., & Nugrahadi, S. (2007). Tsunami vulnerability of buildings and people in South Java – field observations after the July 2006 Java tsunami. *Natural Hazards and Earth System Sciences*, *7*(5), 573–589. https://doi.org/10.5194/nhess-7-573-2007

Resky, A. S. A. (2022). Using Satellite Imagery to Determine Spatiotemporal Patterns of Built-Up Land Use in Relation to the Coastline: An Example from Xiamen, China. *Journal of Coastal Research*, *39*(1). https://doi.org/10.2112/jcoastres-d-22-00023.1

Rimba, A. B., Rimba, A. B., Rimba, A. B., Atmaja, T., Mohan, G., Mohan, G., Chapagain, S. K., Arumansawang, A., Payus, C., Payus, C., Payus, C., Fukushi, K., & Fukushi, K. (2020). Identifying land use and land cover (LULC) change from 2000 to 2025 driven by tourism growth: A study case in Bali. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, 1621–1627. https://doi.org/10.5194/ISPRS-ARCHIVES-XLIII-B3-2020-1621-2020

Scheffers, A. M., May, S. M., & Kelletat, D. H. (2015). *Karst Landscapes: Topographies Sculptured by Dissolution of Rock BT - Landforms of the World with Google Earth: Understanding our Environment* (A. M. Scheffers, S. M. May, & D. H. Kelletat (eds.); pp. 147–161). Springer Netherlands. https://doi.org/10.1007/978-94-017-9713-9_7

Sîrbu, C. C., Iancu, T., Brad, I., Elena Peț, S. M., Iosim, I., Sîrbulescu, C., & Genoveva, B. (2017). Pollution through Tourism and the Managers' Involvement in the Ecologic Education of the Tourists. *Scientific Papers: Animal Science and Biotechnologies*, *50*(2), 147–151.

Sunarta, I. N., & Saifulloh, M. (2022). Coastal tourism: impact for built-up area growth and correlation to vegetation and water indices derived from sentinel-2 remote sensing imagery. *Geojournal of Tourism and Geosites*, *41*(2), 509–516. https://doi.org/10.30892/gtg.41223-857

Surya, B., Salim, A., Sariman, S., Hernita, H., Saleh, H., Suriani, S., Nasrullah, N., & Rasyidi, E. S. (2022). Decline in

Environmental Quality and Spatial Dynamics of New City Area Development Metropolitan Mamminasata, South Sulawesi, Indonesia. *BioRxiv*. https://doi.org/10.1101/2022.01.28.478145

Susanto, D., Faida, L. R. W., & Sunarto. (2019). Pemodelan Efektivitas Hutan Pantai di Cagar Alam Pananjung Pangandaran Sebagai Buffer Tsunami. *Jurnal Ilmu Kehutanan*, *13*(1). https://doi.org/https://doi.org/10.22146/jik.46139

Swarbrooke, P. J. (2020). Chapter 7 The Consumption of Marine Resources by Tourists. In *The Impact of Tourism on the Marine Environment*. Goodfellow Publishers. https://doi.org/http://dx.doi.org/10.23912/9781911635574-4459

Tejakusuma, I. G. (2008). Analisis Pasca Bencana Tsunami Ciamis - Cilacap. *Jurnal Sains Dan Teknologi Indonesia*, *10*(2). https://doi.org/10.29122/jsti.v10i2.798

Touloun, C., & Eddali, R. (2023). Tourist Environmental Behaviour: A narrative review. *11th ABRA International Conference on Environment-Behaviour Studies*, 247–252. https://doi.org/https://doi.org/10.21834/ebpj.v8i23.4510

Vierrether, C. B. (2013). Urban development in karst and collapse-prone geologic environments. *Carbonates and Evaporites*, *28*(1), 23–29. https://doi.org/10.1007/S13146-013-0153-6

Virtriana, R., Ihsan, K. T. N., Anggraini, T. S., Deliar, A., Harto, A. B., Riqqi, A., & Sakti, A. D. (2025). Development of location suitability prediction for health facilities using random forest machine learning in 2030 integrating remote sensing and GIS in West Java, Indonesia. *Environmental Advances*, *19*, 100604. https://doi.org/https://doi.org/10.1016/j.envadv.2024.100604

Yu, J., & Egger, R. (2021). *Tourist Experiences at Overcrowded Attractions: A Text Analytics Approach BT - Information and Communication Technologies in Tourism 2021* (W. Wörndl, C. Koo, & J. L. Stienmetz (eds.); pp. 231–243). Springer International Publishing.