Spatial pattern change of land use change in tidal flood area of the coast of Cirebon Regency

I P A Andika, M P Tambunan and K Marko

Department of Geography, Faculty of Mathematics and Natural Sciences (FMIPA), Universitas Indonesia, Depok 16424, Indonesia

Corresponding author’s email: mangapul.parlindungan@ui.ac.id

Abstract. Tidal flood is one of the threats found in the coastal areas of Cirebon Regency, especially in Pangenan, Gebang and Losari Districts. The changing coastal conditions and the changing land use have worsened the tidal flood. The purpose of this research is to analyse the spatial pattern of land use change in the tidal flood area. This study uses spatial analysis and temporal and spatial metrics. Temporal, spatial analysis is used to see changes in land use in tidal flood areas in 2002, 2009, and 2019, while spatial metrics are used to see these patterns, especially aggregation and diversity. The results of processing show that changes in land use in 2002–2019 were dominated by ponds and irrigated rice fields. The largest land use area in the tidal flood area is in ponds, but the increase has continued to occur in residential and built-up land from 2002 to 2019. Overall, the spatial metric results show that land use fragmentation in the coastal zone of Cirebon Regency in the tidal flood area is increasing. However, the development of land use in the coastal district of Cirebon Regency is low due to tidal flood.

Keywords: Tidal flood, Cirebon Regency, spatial metric

1. Introduction

Tidal flood is a physical condition of a flood or a puddle caused by rising sea levels [1]. Tidal flood occurred when the level of the tide is higher than the ground [1]. One of the main causes of tidal flood is climate change. The climate change causes global sea level to increase by 3.1 mm per year, since 1990 [2]. Besides climate change, one of the major human activities that make tidal flood worse is urbanization and industrialization [3]. Urbanization and industrialization cause water need to increase, and if not controlled, can cause overexploitation of ground water [3]. Continuous groundwater pumping can cause the land to decline and the sea level increase [3].

The coast of Cirebon Regency is one of the area prone to tidal flood. Topographical conditions close to the sea cause Cirebon to be exposed to tidal phenomena and sea waves that have the potential to become tidal. Areas that are frequently affected by tidal flood are Pangenan District, Gebang District, and Losari District [4]. The 3 districts are the most common areas hit by tidal flood with frequency up to more than 3 times a year [4]. In 2018, tidal flood inundated the coast of Cirebon Regency with area of 6569 ha [5]. The tidal flood was estimated to cause loss about Rp 48,691,991 to the pond land use [6].

Increased land use change made the problem of tidal flood even worse. As much as 75% of the mangrove forest area in Coastal Cirebon has been damaged [6]. In Pangenan, Gebang, and Losari sub-districts, mangrove forests experienced a reduction from 2004 to 2014 [6]. Besides land conversion,
the Cirebon Regency coastal zone also experienced accretion and abrasion. The changes in coastline are caused by abrasion and accretion from 1954 to 2004 [6]. Changes in the coastline because of abrasion and accretion have caused the area of tidal flood that has become more widespread [7, 8]. Changes in land use and tidal flood that occur need to be researched to know and analyze the affected areas.

The purpose of this research is to analyze spatial pattern of land use change in the coast of Cirebon Regency (Pangenan, Gebang, and Losari). This research uses spatial and temporal data to analyze the change of pattern in land use located in tidal flood area. The years used for analyzing the change of land use pattern are 2002, 2009, and 2019.

2. Methodology

The research is done in the coast of Cirebon Regency. The coastline of Cirebon Regency as a whole is located in the position of 6°32'30" – 6°50' LS dan 108°30' – 108°50' BT East Longitude is bordered by Indramayu Regency in the west-north and the eastern part with Brebes Regency, Central Java Province. The research area does not cover the entire area of the coast of Cirebon Regency, but only Pangenan District, Gebang District, and Losari District. The research area can be seen in figure 1.

In this study, the data used were temporal geospatial data in the coastal Cirebon Regency. The data used in this research are all secondary data. The data used is in the form of land use which is obtained from the Google Earth Pro image with the years used are 2002, 2009, and 2019, and tidal flood which is secondary data. The data used for this research can be seen in table 1.

2.1. Land use change mapping in tidal flood area

The tidal flood area used is secondary data. Secondary data used in this study are based on the results of a field survey conducted by [4]. After that, the tidal flood area in the coast of Cirebon Regency was modified to fit the area in 2002, 2009 and 2019.

Land use classification and changes are obtained from the Landsat imagery of Google Earth Pro with the years used are 2002, 2009, and 2019. Landsat image processing is done by geo-referencing first with ArcMap 10.4 software to match the research area taken. After that, on-screen digitization was performed with ArcMap 10.4 software to obtain land use classification. Digitization is carried out using a scale of 1: 25000 as well as the provisions of the 2010 SNI BIG classification.
Table 1. Data used in research

| No | Data type       | Source                          |
|----|-----------------|---------------------------------|
| 1  | Tidal Flood     | [4]                             |
| 2  | Basic shapefile | Badan Informasi Geospasial      |
| 3  | Land Use 2002, 2009, dan 2019 | Landsat Imagery Google Earth Pro |

Table 2. Selection of metrics

| Metric                          | Category                        |
|---------------------------------|---------------------------------|
| Aggregation                     | Number of Patch                 |
|                                 | Patch Density                   |
|                                 | Interpersion and Juxtaposition Index (IJI) |
|                                 | Percentage of Like Adjacencies (PLADJ) |
| Diversity                       | Shannon's Diversity Index (SHDI) |
|                                 | Shannon's Evenness Index (SHEI)  |

Land use in tidal flood areas was obtained from land use data and tidal flood areas in 2002, 2009 and 2019. The process carried out to obtain tidal flood areas is by overlay analysis. The overlay process is carried out in ArcMap 10.4 software.

2.2. Spatial patterns of land use in the tidal flood area

The spatial pattern of land use in the tidal flood area was obtained using the spatial metric method with the help of the Fragstats software. Spatial metric shows the placement and arrangement of an object on earth. The metrics used in this study are class and patch levels. The categories used are aggregation and diversity. In this metric, there are several calculation methods that will be used in this research. Each calculation method has its own function in explaining spatial patterns. Metrics used in this research are from [9]. The metric used can be seen in table 2.

3. Results and discussion

3.1. Land use change in tidal flood area

The classification of land use in the coastal district of Cirebon Regency (Pangenan, Gebang, and Losari Districts), was obtained from Google Earth Pro Landsat imagery for 2002, 2009, and 2019. Based on the results of on-screen interpretation and digitization carried out on Google Earth imagery in 2002, 2009, and 2019, obtained 12 land use classes according to SNI BIG in 2010. The resulting classification is a stretch of sand, mangrove forest, arterial road, garden, built-up land, undeveloped land, settlements, irrigated rice fields, shrubs, and ponds. The land use in tidal flood area during year 2002, 2009, and 2019 can be seen in figure 2.

After getting the land use for each year (2002, 2009, 2019), the land use area are calculated to obtain the change of the area. The largest area in the tidal flood area on the coast of Cirebon Regency (Pangenan, Gebang and Losari Districts) is dominated by ponds. Although dominated by ponds, the upward trend is in the use of built-up land and settlements. In 2002–2019, the area of built-up in the tidal flood area increased by 17 ha and in settlements increased by 32.13 ha. This increase indicates that there is urbanization occurring in the coastal area of Cirebon Regency, even in the tidal flood area. The phenomenon of urbanization can be marked by an increase in settlements and built-up land [10].
Based on the result of table 3, there is an increase in area for settlement and built-up land use in 2002–2019. The area of settlement increased by 32.13 ha and built-up land increased by 17 ha. The area of land use can be seen in table 3.

![Figure 2. Land use in tidal flood area](image)

| Land use type          | 2002 (ha) | 2009 (ha) | 2019 (ha) |
|------------------------|-----------|-----------|-----------|
| Sand                   | 374.17    | 119.71    | 238.65    |
| Mangrove forest        | 118.05    | 113.74    | 193.47    |
| Road                   | 5.08      | 1.72      | 4.41      |
| Garden                 | 0.00      | 0.00      | 0.00      |
| Built-up land          | 1.63      | 6.27      | 18.63     |
| Undeveloped land       | 1.83      | 8.11      | 50.51     |
| Settlement             | 90.88     | 113.70    | 123.01    |
| Irrigated rice field   | 732.70    | 573.90    | 518.72    |
| Shrub area             | 19.15     | 47.57     | 52.86     |
| River                  | 126.32    | 126.47    | 131.42    |
| Pond                   | 3891.11   | 3867.04   | 4388.78   |
In addition, the area of irrigated rice fields in the tidal flood area continued to decline in the period 2002–2019. This was caused by tidal flood which could give large losses to irrigated rice fields. Tidal flood in irrigated rice fields can reduce productivity and make the land difficult to replant [11, 12]. The area of ponds in tidal flood areas decreased in 2002–2009 but increased in 2009–2019. Although located in tidal flood areas, the increase in 2019 was the most extensive than in 2002 and 2009. This is because ponds are land that is always used for the community’s economy in the coastal district of Cirebon Regency. Despite of the increase in urban land use type, there is also a significant increase in pond land use type. This is due to the characteristic of the coast itself. The characteristic of the muddy coast makes the people of Cirebon Regency coastal use the area as a pond area [13]. Based on the result in table 3, the area of the pond land use type is increased by 497.67 ha from 2002–2019.

3.2. Spatial metric result
The results of the spatial metric are used to explain the spatial patterns of land use in tidal flood areas. Spatial metric processing is carried out according to the type of metric previously selected. The results of the spatial metric can be seen in the discussion below.

3.2.1. Aggregation

a) Number of Patches (NP)
Number of Patch is a calculation of the patch density based on the number of patches. The greater the value, the greater the level of fragmentation, conversely, if it is smaller, the smaller the level of fragmentation. The graph of the NP value can be seen in figure 3.

The NP value in each district can be seen in figure 3. For period 2002–2009, in Pangenan District, the NP value increased by 29, in Gebang District by 19, and in Losari District by 18. However, in the 2009–2019 period, the NP value in the District Pangenan and Gebang are decreasing. In that year, the NP value of Pangeann District decreased by 12 and Gebang District decreased by 5. In Losari District, the NP value increased by 20.

Overall, the NP value in the coastal areas of Cirebon Regency (Pangenan, Gebang, and Losari Districts) in the tidal flood area continues to increase. The NP value increased by 75 from 2002–2019. Despite tidal flood in the area, the level of land use fragmentation has increased. This increase can cause losses if the NP value continues to increase per year.

b) Patch Density (PD)
Patch density indicates the density of patches. The higher the value, the lower the density becomes. Based on the figure 4, the PD value in each sub-district from 2002 to 2019 has a similar trend. On the coast of Cirebon Regency (Pangenan, Gebang, and Losari Districts), from 2002 to 2009, there was a decrease in density. The PD value in Pangenan District increased by 2.31/100 ha, in Gebang District increased by 2.31/100 ha, and in Losari District by 0.77/100 ha. In 2009–2019, there was an increase in density in Pangenan and Gebang Districts, but there was a decrease in density in Losari District. The PD value in Pangeanan and Gebang Districts decreased by 2.15/100 ha and 0.88/100 ha. In Losari District, the PD value increased by 0.2/100 ha.

Overall, the value of PD has increased in the period 2002–2009 but decreased slightly in the period 2009–2019. In 2002–2009 there was a decrease in density, but in 2009–2019 there was an increase in density. The value of PD in 2002–2009 increased by 1.52/100 ha, then in 2009–2019 decreased by 0.29/100 ha.

c) Percentage of Like Adjacencies (PLADJ)
PLADJ is a metric that shows the level of cohesiveness. The level of cohesiveness can be seen in figure 5. The higher the PLADJ value indicates the patches are more compact. In Pangenan, Gebang and Losari Districts has increased in 2002–2009 but decreased drastically in 2009–2019.
In 2002–2009, the PLADJ value of Pangenan District increased by 0.41 %, in Gebang District by 0.61 %, and in Losari District at 0.12%. In 2009–2019, the PLADJ value in each sub-district decreased. In Pangenan District, the PLADJ value decreased by 0.1%, in Gebang District it decreased by 2.17 %, and in Losari District it decreased by 0.18 %.

Overall, the cohesiveness rate from 2002 to 2019 has had its ups and downs. The level of cohesiveness increased in 2002–2009 but decreased in 2009–2019. In 2002–2009, the PLADJ value increased by 0.41 % and in 2009–2019 decreased by 0.7 %.

d) Interpersion and Juxtaposition Index (IJI)
Interpersion and Juxtaposition Index shows the calculation of the fragmentation index of a patch, in this case land use, in an area. The greater the IJI value, the greater the fragmentation that occurs in a land use. The IJI value can be seen in figure 6. Changes in the value of IJI in the tidal flood areas from 2002 to 2019 have a similar trend. In Losari and Gebang Districts, from 2002 to 2009 there was a decrease in fragmentation that occurred, while in Pangenan District the fragmentation that occurred continued to increase from 2002 to 2019. In 2002–2009, the IJI value of Losari District decreased by 0.16 % and in the District Gebang 8.28 %. In Pangenan District, the IJI score continued to increase by 4.77 %.

Overall, the fragmentation that occurs in the tidal flood area in coast of Cirebon Regency continues to increase. The increase in fragmentation was indicated by the IJI value which increased in 2002–2019. The IJI value that increased from 2002 to 2019 was 5.13 %. The increasing value of IJI shows an increase in fragmentation of land use in tidal flood areas.

![Figure 3. NP value graph](image1)

![Figure 4. PD value graph](image2)
3.2.2. Diversity

a) Shannon’s Diversity Index (SHDI)
Shannon’s Diversity Index is a landscape level calculation metric that measures the diversity level of each patch. The result of SHDI value in this research can be seen in figure 7. In this study, SHDI shows a large development pattern and diversity of land uses that are affected by tidal flood. The SHDI value that is getting closer to 0 will indicate greater diversity, while if it is getting bigger, the opposite will happen. The trend of changes in the SHDI value in each district is different. In Pangenan District, the SHDI value has decreased and increased. In 2002–2009 there was a decrease in the diversity level that occurred by 0.05. In 2009–2019, Pangenan District experienced an increase in land use diversity. The value of SHDI increased by 0.35 in 2019. In Gebang District, the change in the SHDI value has a trend that is almost the same as that of Pangenan District. In 2002–2009 there was a decrease in the diversity level that occurred by 0.12. After that, the level of diversity in land use occurred in the period 2009–2019. The value of SHDI increased by 0.2. In Losari District, the trend of changes in the value of SHDI has a different trend. The level of diversity in land use for the period 2002–2019 continues to decline. The SHDI value in Losari District decreased by 0.26.

b) Shannon’s Evenness Index (SHEI)
The pattern of SHEI value development has a pattern that is almost the same as the SHDI value. The value of SHEI can be seen in figure 8. The SHEI value from the 2002–2019 period has changed. In the period 2002–2009 there was a decrease in the level of even distribution of land use diversity.
In 2002–2009, the SHEI value decreased by 0.06. Then, this value has increased by 0.3 in 2019. Each district has a different trend of change. In Pangenan District, the land use affected by tidal flood continues to have more diversity, which changes every year. In 2002–2009 the SHEI value decreased by 0.02. In 2009–2019 the level of diversity was evenly distributed. The SHEI value has increased by 0.15 in 2019. In Gebang District, the SHEI value trend has also increased and decreased. In 2002–2009, the diversity level decreased with the SHEI value decreasing by 0.1. In 2009–2019, the level of equity was higher, with the SHEI value increasing by 0.11. In Losari District, the level of diversity is increasingly uneven. The SHEI value from 2002 to 2019 continued to decline. In 2002–2019 there was a decrease of 0.25.

3.3. Spatial pattern of land use in tidal flood area
Based on the results of previous processing, the coastal area of Cirebon Regency (Pangenan, Gebang, and Losari Districts), there is a change in land use in the tidal flood area in 2002, 2009 and 2019. Changes in land use in tidal flood areas continue to increase in settlements, built-up land, and ponds. This increase indicates the existence of an urbanization phenomenon that is occurring, even in the tidal flood area in the coastal area of Cirebon Regency [10]. There are several patterns of land use change that can occur in an area such as aggregation pattern, a linear pattern, a smudge pattern, and a leapfrog [14]. Determination of this pattern can be determined by the results of spatial metric processing that has been done previously. Based on the results of spatial metric processing, it was found that the spatial pattern of land use change in the coastal zone of Cirebon Regency in the tidal flood area has a linear pattern. The linear pattern is characterized by an increase or stability in aggregation and a decrease in the level of cohesiveness in an area [14].
Figure 9. Illustration of fragmentation with linear patterns (a) 2002, (b) 2009 and (c) 2019.

The linear pattern is also characterized by changes in land use that tend to occur in the road / transportation network. The linear fragment illustration can be seen in figure 9.

This aggregation value can be seen in the increase in the value of NP, PD, and IJI which increased and was stable in the period 2002–2019. This increase indicates an increase in fragmentation in land use changes in the tidal flood area in the coastal area of Cirebon Regency in the tidal flood area. Land use in tidal flood areas is also increasingly aggregated, which indicates that land use in tidal flood areas is increasing. In addition, a decrease in land use cohesiveness can be seen in PLADJ. Even though it experienced an increase in 2002–2009, in the 2002–2019 period the value was getting smaller compared to that. This indicates that there is a decrease in the level of cohesiveness in the tidal flood area in coastal Cirebon Regency. Meanwhile, the metric for the level of diversity shows that the value of SHDI and SHEI has decreased in the period 2002–2009 but has increased in 2009–2019.

However, the SHDI and SHEI values on the coastal zone of Cirebon Regency have low values. The low diversity value indicates that the level of land use development in the coastal district of Cirebon Regency tends to be low. This is because the tidal flood that occurs is detrimental to areas that have been previously submerged. Although developed land and settlements have an ever-increasing value, irrigated rice fields and ponds have the greatest impact and are the widest inundation by tidal flood. Irrigation rice fields inundated by tidal floods will experience a decrease in productivity and will be abandoned by their owners. Meanwhile, tidal flood also has a big impact because it reduces the level of productivity and the condition of the waters becomes unsuitable for being used as ponds again [12, 13]. Overall, the existence of urban sprawl or urbanization in the coastal area of Cirebon Regency in the tidal flood area can cause great losses. In areas that are quite often inundated by tidal flood, land conversion occurs which can make losses even greater.

4. Conclusion
Based on the results, it can be concluded that the coast of Cirebon Regency suffer land use dynamic. The most common land use in the area are irrigated rice field and pond. In tidal flood area however, the largest land use is still pond, but the increase happened to settlement and built-up land. The result of spatial metric showed that the fragmentation of land use from 2002 to 2019 increases and becoming more disaggregated while the diversity has small value and decreasing. The result of the spatial metric also shows that the land use pattern change has a linear pattern. The pattern can be identified by the increase of aggregation and decrease of cohesiveness.

References
[1] Rahma N N, Maryono M and Widjanarko W 2019 E3S Web of Conferences 125 07020
[2] Cazenave A, Dieng H -B, Meyssignac B and Schuckmann K, Decharme B and Berthier E 2014 Nature Climate Change 4
[3] Sarah D and Soebowo E 2018 IOP Conf. Ser.: Earth Environ. Sci. 118 012042
[4] Rachmawati D and Saraswati R 2019 Kerentanan Wilayah terhadap Banjir Rob di Pesisir Cirebon in Simposium Infrastruktur Informasi Geospasial (Yogyakarta) (Yogyakarta: Department of Geodetic Engineering, Faculty of Engineering, Universitas Gadjah Mada) p27

[5] Nirwansyah A W and Braun B 2019 ISPRS Int. J. Geo-Inf. 8 451

[6] Raharjo P, Setiady D, Zallesa S and Putri E 2016 Jurnal Geologi Kelautan 13 9-24

[7] Safitri F, Suryanti S and Febrianto S 2019 Jurnal Ilmiah Geomatika 25 37-46

[8] Sudarsono B 2011 TEKNIK 32 163-70

[9] Wijaya A, Susetyo C, Diny A Q, Nabila D H, Pamungkas R P, Hadikunnuha and Pratomoatmojo N A 2018 Research Journal of Applied Sciences 13 349-57

[10] Sahalu A G 2014 Analysis of Urban Land Use and Land Cover Change Master thesis (Castellon: Department of Mathematics, Universitat Jaume I)

[11] Marfai M A, Cahyadi A and Kasbullah A A 2017 Dampak Bencana Banjir Pesisir dan Adaptasi Masyarakat Terhadapnya Di Kabupaten Pekalongan available at doi:10.31227/osf.io/m273k

[12] Nicholls R J and de la Vega-Leinert A C 2008 Journal of Coastal Research 24 285-7

[13] Wahyuningsih S and Fatimatuzaahroh F 2019 Jurnal Ilmiah Indonesia 4 116-30

[14] Aguilera F, Valenzuela L M and Botequilha-Leitão A 2011 Landscape and Urban Planning 99 226-38