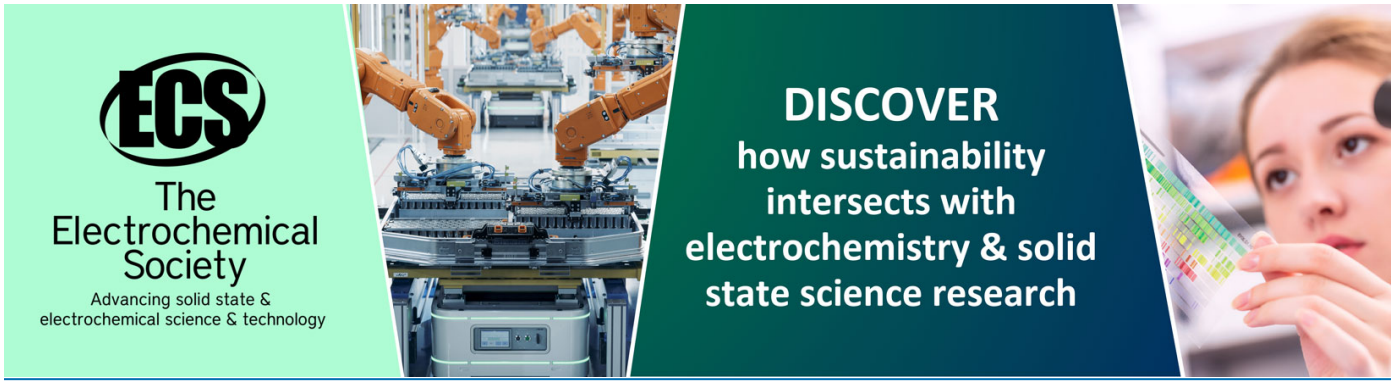
Preliminary study of *coastal circulation cells* in the coastal area of Kendal, Indonesia



Preliminary study of *coastal circulation cells* in the coastal area of Kendal, Indonesia

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Abstract. The objective of this study was to recognise the hydrodynamic pattern of sea surface current to find the potential of coastal circulation cells in Kendal coastal area. The initial identification of coastal circulation cells in this study used the modification of the band ratio method. Further identification related to the availability of coastal circulation cells utilise the results of aerial photography as a process of detailed validation and has never been done before. The results showed that there was a similar potential of coastal circulation cells in different seasons. In detail, the coastal circulation cells obtained the suspension of sediment, with also the potential of nutrient and alga, namely Rhodophyta Sp. Considered by the colour shown in the photograph of UAV.

1. Introduction

Land, atmosphere, and sea are the three primary systems on Earth's surface [1]. These three systems have different processes and affect each other with complex performance. Coastal area is the area that became the meeting between those three primary systems which include the hydrosphere, pedosphere and lithosphere, atmosphere, and anthroposphere [2].

The coastal dynamic is complicated. Wind, waves, currents, and tides are the four major forces that cause the complexity of the coastal dynamics [3]. The primary current is the sea surface currents with a depth of fewer than 100 m below the sea level [4]. The influence of these four forces as a form of hydrodynamics can occur either directly or indirectly.

The hydrodynamic aspect of the coastal area is measured by the presence of wind, waves, currents, and tides [3]. Discussion of issues of hydrodynamics in coastal areas is also much mentioned about sea level rise. However, this event is explained by [5] as the impact of land subsidence. Thus, it can be interpreted sea level rise is not a major study of the hydrodynamic aspects of the coastal areas.

Coastal circulation cells are mass of water circulation movements occurring both seasonally and yearly [6], with their forming forces being wind or current [7] [8] [9] [10]. The earlier concept of coastal circulation cell [7] said that it is formed through a combination of normal current (onshore-offshore current) with long-shore current then caused rip current. It was confirmed by another research [8], that the location of coastal circulation cell is nearshore zone. The concepts that exist so far do not discuss the coastal circulation cell firmly, with the meaning of the concept is a patent concept. One of the meanings of coastal circulation cells can be defined as the accumulation of nutrients [10] or only limited to sediments in the absence of nutrients.

The study of coastal areas is closely related to the process of sedimentation and erosion as the primary processes of coastal dynamics [11] [12]. Two processes in the coastal area occur

due to the direct influence of winds that induce waves and currents movement [13] [14] [15] [16]. The direct influence of waves directly affect the coastal configuration [17] and then the sediment material will be carried by sea surface currents [18]. Based on the fact that there is a study of sea hydrodynamics aspects related to the winds, waves, and sea surface currents as the main trigger of the coastal dynamics becomes important to be done.

The existence of the coastal dynamics certainly gives its effects for the areas that receive different processes and lead to the occurrence of disasters. The variability of the effects of the coastal dynamic is very clearly indicated in the northern region of Central Java. This can be explained by the results of previous research [19] [20], it is explained that Tegal, Pekalongan and Demak Regencies are areas of accelerated erosion. Based on those research, there are intensive erosion effects recorded in Pekalongan Regency with erosion that continues to occur throughout the year with the addition of 1 m each year. The effects of other coastal dynamics also occurred in the Demak with tidal inundation events that forced hundreds of families to move from the previous residence which means they lose their homes [20]. This loss can be categorised as a disaster event.

Disaster perceived from the dynamics of the coastal area in the northern part of Central Java is reinforced by high population growth, such as the one that occurred in the coastal area of Kendal Regency. This is due to the presence of the most densely populated national transportation routes in Java Island, namely Jalur Pantai Utara [21]. The optimisation of industrial activities, especially in the area of Kendal Regency [22] also contribute the population growth. Apart from aspects of the population, the dominance of the fluvial process leads to thick and widespread sediment deposition throughout the northern part of Central Java, the effect being the loose soil material that tends to lose and has a high degree of erosivity. Based on the mentioned facts, the northern region of Central Java is mainly for Kendal Regency to be an area worth examining in this study.

This research will be obtained data of field result and secondary data related to sea surface current data as main media forming coastal circulation cells. It is said so because the wind and waves tend to have a laminar movement and direction [23] [8] [3] [24]. So that, sea surface current is considered as the greatest potential for driving the formation of coastal circulation cells. The coastal circulation cells are necessary to be studied as previous studies [7] [8] [9], explaining the potentials contained in circulation cells such as marine nutrients, sediments, and potential of hazards.

The high intensity of the interaction between the coastal dynamic and coastal circulation cells is an interesting fact since both are triggered by the same factor, which is sea surface current as part of the ocean hydrodynamics aspect [7] [8]. Bodri River as a major river in Kendal gives two possibilities which have the potential to either provide sedimentation effects or become nutritional contributors [10] or even other toxic waste and suspension for marine life in Kendal. Based on previous studies, sedimentation in Kendal is high with sedimentation up to 1.9 km^2 during ten years of observation [25]. The sedimentation comes from the Bodri River. Sedimentation occurring in the Kendal coastal area has potential to carry nutrients or even waste along the Kendal coastal area. Even so this condition can certainly cause problems. The important preventive steps were taken including monitoring the availability of coastal circulation cells that can determine the accumulation of suspension in the coastal area.

The objective of this study is to assess the coastal circulation cells in the coastal area of Kendal, Central Java. This objective will be done by modification of band ratio as the initial

identification of coastal circulation cells and conduct field validation of the availability of coastal circulation cells.

2. Methodology

The research area of this work set in District Patebon with Pidodo Kulon Village as the only one area occupied the main river mouth. Current measurements are focused on sea surface currents. Hydrodynamic analyses were performed in the nearshore zone behind the breaker zone with the assumption that sea surface current energy is stabled from the reduction of the depth.

This study analyzed using ENVI software on secondary data of Landsat 5 TM and 8 OLI / TIRS Image for 2008-2017 Path 120-121 and Row 65 [26]. The result of ENVI software analysis was validated by using primary data in the form of Unmanned Aerial Vehicle (UAV) photograph. Primary data collection requires tools such as GPS, UAV, and motorboat.

Determination of the sample for the study area is done with the evidence of the satellite image interpretation to obtain the potential of coastal circulation cells. Sample determination was achieved by using Landsat 5 TM and 8 OLI / TIRS images in 2008-2017 with paths 120 and 121 and row 65 or covering all areas of Central Java. The observations from 2008-2017 were included in the medium-term variations scale. The scale is one of the scaling [27] which is defined as the systematic trend line of shoreline variations. Other scales are long-term variations (100-1000 years) and short-term fluctuations (short-term fluctuations). The acquisition of the sample area considered by the location which is semi-closed (bay) or open water. This consideration as revealed [28] those tidal factors and other physical factors are more influential on the semi-closed seas (bay) that mean there is an opposite condition for open water. This interpretation is also used to obtain locations with potential coastal circulation cells. The areas with potential coastal circulation cells or anomalous findings in the nearshore zone may be the location of the sample.

Envi software was used to process the image of Landsat with modification of band ratio method. Band ratio method was used from the beginning of site selection to the end of the analysis to identify potential locations related to the availability of coastal circulation cells. The band ratio method was chosen because it is an effective method of displaying certain objects and will be more easily detected due to differences in them [29]. Data analysis was performed in the descriptive analysis of hydrodynamic model results with field data validation, coastal circulation cell findings and suspension analysis. The research flow diagram is shown in figure 1.

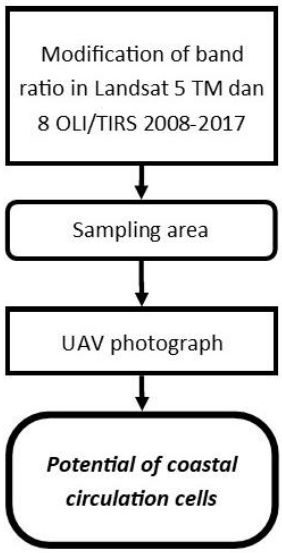

Figure 1. Research flow diagram.

3. Result and Discussion

The result of band ratio modification in band 3/2 indicated a tendency of sediment suspension accumulation at the end of river mouth of Bodri River (figure 2). Several circular movement appearances were also shown in the modified results. These were shown in Figure 6.7 and 6.10 on 21st November 2015 and 25th May 2017. Both sequentially are visible on months that tend to have entered the western and eastern seasons. Circulation patterns that occur more directed to the northeast from the river mouth of Bodri River both in the trend of the western and eastern seasons. This same characteristic could be interpreted that the potential of coastal circulation cells based on two distinct seasons has the same suspension accumulation site, i.e. a radius of less than 5 km from the tip of the river mouth of the Bodri River.

The result of band ratio modification in band 3/2 Landsat OLI/TIRS showed the existence of suspension in the potential coastal circulation cells. The suspension creates a different pattern. Figure 2 is the result of the band ratio modification of Landsat 8 OLI/TIRS dated July 28th, 2008. This figure showed the suspension tends not to be seen by the image during recording. That happened because July is a month with low rainfall intensity so that fewer sediment were brought into the sea. This condition caused the nutrients in the sea to decrease so that algae growth also reduced. So that was not recorded the suspension on Landsat 8 OLI/TIRS recording on July 28th, 2008.

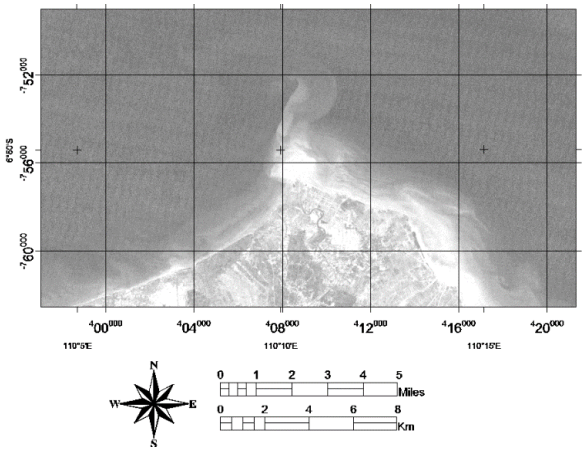

Figure 2. The result of band ratio modification in band 3/2 Landsat 8 OLI / TIRS on July 28th, 2008.

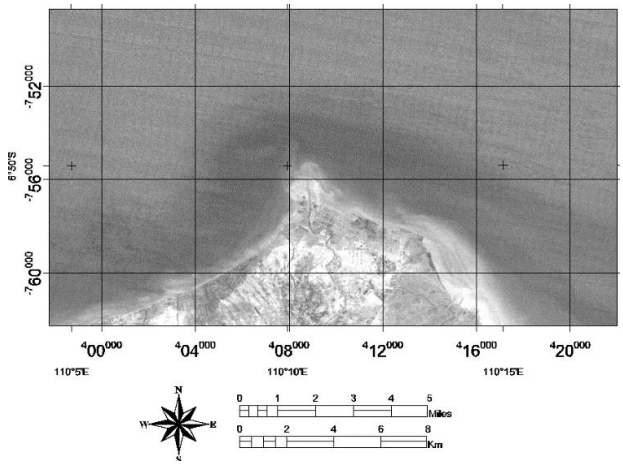

Figure 3. The result of band ratio modification in band 3/2 Landsat 8 OLI / TIRS on October 19th, 2009.

October is the beginning of the west season with the intensity of moderate rain. Figure 4 showed a suspension though not very clear. This happened because the sediment that carried nutrients began to carry into the sea, so the suspension of algae also began to grow. Conditions in November 2011 showed almost the same conditions, namely the suspension that was starting to look although still vague.

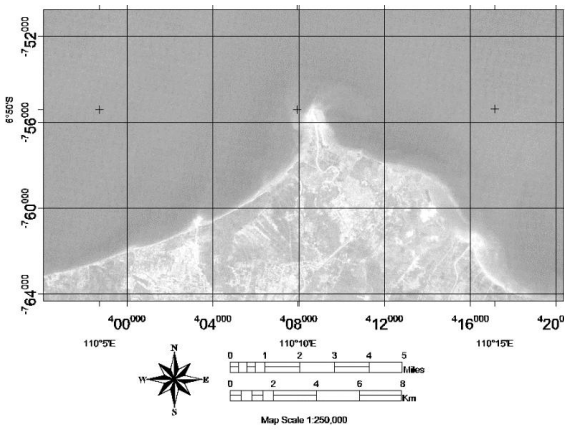

Figure 4. The result of band ratio modification in band 3/2 Landsat 8 OLI/TIRS on November 2nd, 2011.

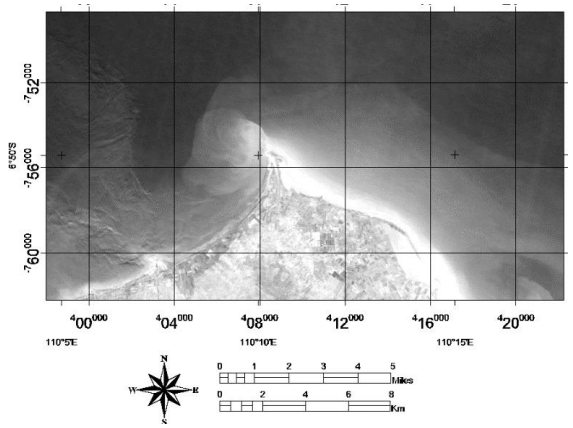

Figure 5. The result of band ratio modification in band 3/2 Landsat 8 OLI / TIRS on September 12th, 2013.

Figure 5 was the result of the band ratio modification in band 3/2 Landsat 8 OLI/TIRS dated September 12th, 2013. This figure showed a visible suspension in the nearshore zone. That happened because the intensity of rain had tended from medium to high. So that suspended sediment that carried nutrients were accumulated in the nearshore zone. This condition allowed the algae in the ocean to quickly grown and developed. This suspension of sediment, nutrients and algae were captured by Landsat 8 OLI/TIRS on September 12th, 2013. The same conditions were also recorded on the result of band ratio modification of Landsat images in figure 6, figure 7, figure 8, figure 9, and figure 10.

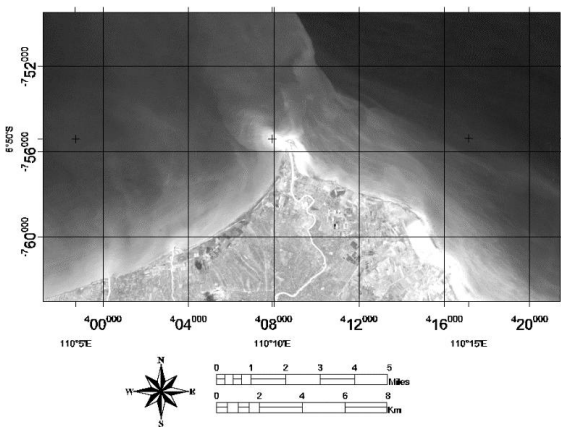

Figure 6. The results of band ratio modification in band 3/2 Landsat 8 OLI/TIRS on May 10th, 2014.

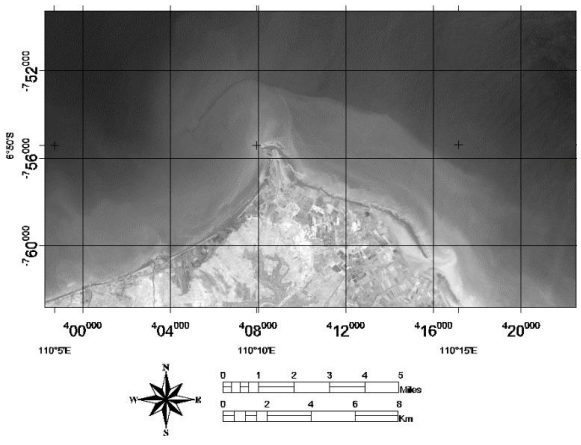

Figure 7. The results of band ratio modification in band 3/2 Landsat 8 OLI/TIRS on November 2nd, 2014.

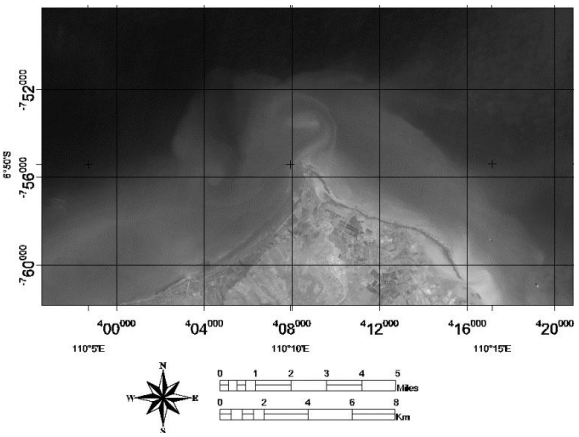

Figure 8. The results of band ratio modification in band 3/2 Landsat 8 OLI/TIRS on November 21st, 2015.

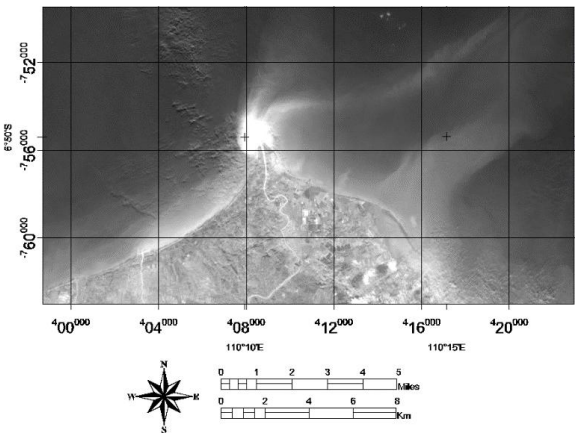

Figure 9. The results of band ratio modification in band 3/2 Landsat 8 OLI/TIRS on March 28th, 2016.

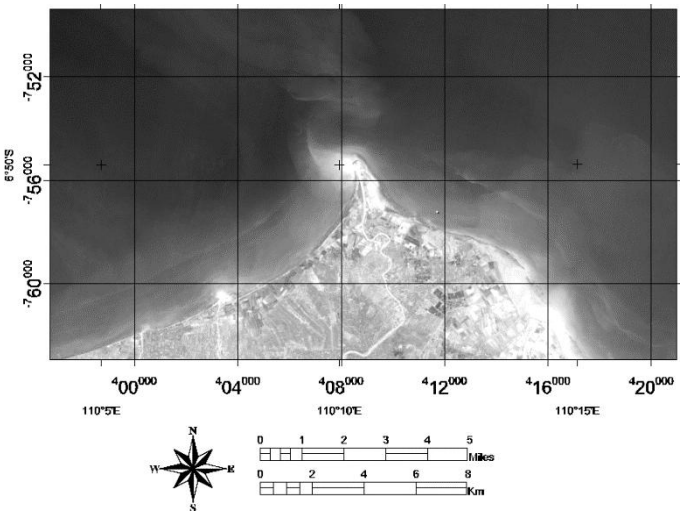

Figure 10. The results of band ratio modification in band 3/2 Landsat 8 OLI / TIRS on May 1st, 2017.

Field validation by UAV photograph showed part of the more detailed estimate of coastal circulation cells with laminar current patterns. Figure 12 shows the laminar current movement with an accumulation of brown suspension. This accumulation could be a sediment suspension that allowed the presence of nutrients carried by sea surface currents. It was said so because the sediment suspension was formed, alongside the pattern of purple laminar sea surface current flow (figure 12) which could be estimated as *Rhodophyta Sp* [30]. The purple colour of the laminar current flow was not said to be a waste as it should be. If the flow of the laminar stream was a waste that should be mixed with the brown sediment suspension. But the purple suspension naturally separated from brown suspensions, so it was certain that the purple suspension was a marine biota that colonizes the sea surface current. Thus the sediment suspension carried by surface currents is a sediment with nutrient

accumulation [10]. The accumulation of nutrients was carried by the Bodri River flow into a single unity of potential coastal circulation cells in the sea near the mouth of the Bodri River.

Figure 11. Images of sea-surface currents carrying possible sediment suspensions containing nutrients.

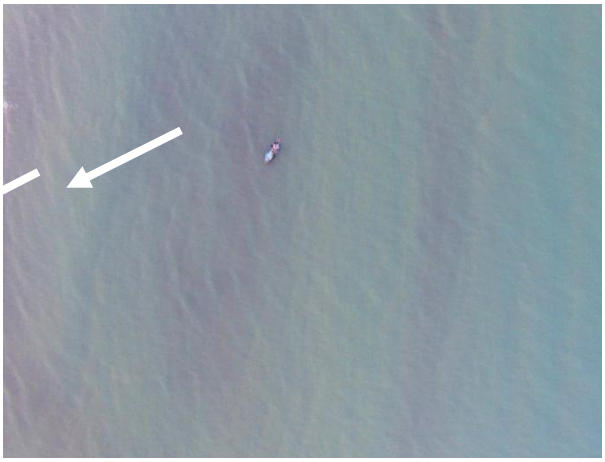

Figure 12. Image of the purple sea surface current movement, it is probably *Rhodophyta Sp*.

4. Conclusion

The potential of coastal circulation cells in Kendal coastal area showed the tendency of occurrence in the tip of the mouth of the Bodri River. The same characteristic pattern of circulation occurs in both east and west seasons with an inclination up to 22^{o} to the northeast. Field validation results using a UAV for circulation analysis in which there was a difference of suspension on each surface current flow, which is possible as the accumulation of sediment and nutrient followed by red algae or *Rhodophyta Sp*.

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