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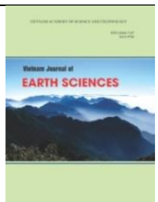

Monitoring of coastline change using Sentinel-2A and Landsat 8 data, a case study of Cam Pha city - Quang Ninh province

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ABSTRACT

The main purpose of this study is to evaluate the performance of Sentinel - 2A and Landsat 8 data in monitoring coastline change from 1999 to 2018 at Cam Pha city, Quang Ninh province. Both data were collected under similar conditions of time and weather features to minimize the differences in interpretation results caused by these factors. The coastline was extracted from Sentinel-2A and Landsat 8 in 2018 by using the Normalized Difference Water Index (NDWI). Coastline map from Quang Ninh Department of Natural Resources and Environment with a scale of 1: 50.000 in 1999 was used as a reference of the same mask and overlaid on coastline maps in 2018 to identify the changes in the study area. The data from fieldwork and Google Earth was used to evaluate the accuracy and make comparative comments. The results presented that changes dramatically occurred between 1999 and 2018 with the accretion process prevailing. This process took place quite strongly on the East and Southeast coast while the erosion process only occurred with small areas at scattered points in the study area. The results also showed that the overall classification accuracy of Sentinel-2A imagery (95.0%) was slightly higher than that of Landsat-8 (87.5%). The combined use of Landsat-Sentinel-2 imagery is expected to generate reliable data records for continuous detecting of coastline changes.

Keywords: Coastline change, Sentinel-2A, Landsat 8, normalized difference water index.

1. Introduction

The coastal zone is known as an interface between the land and sea and considered the most complex and dynamic environment on the planet (Winarso and Budhiman, 2001; Dethier and Harper, 2011). It is also known as the richest place in natural resources and diversity of ecosystems (Dong Jiang et al., 2016), high biological productivity, and the largest fishery potential (Werner and Blanton, 2008). Consequently, nearly 2.4 billion people

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(about 40% of the world's population) live within 100 km (60 miles) of the coast and is the location of 75% of cities and megacities according to the statistic of the United Nations in 2017. However, coastal zones are continually being changed by the dynamic interaction of physical processes as well as undergo more localized short-term change. Especially, human activities are causing enormous impacts that increase the rate of change and creating new changes in the structure and functioning of the coastal zone in recent years (Le Tissier et al., 2006). Quang Ninh is a key province in the economic development strategy in the North of Vietnam with a coastline of 250 km. The exploitation of marine resources has brought a huge economic benefit to Quang Ninh every year. However, these activities make the coastal erosion - accretion process become more quickly and complicated, typically in the coastal area of Cam Pha city (Pham Huy Tien et al., 2002). Therefore, coastline change detection and mapping keep an important role in coastal resource management, coastal environmental protection, and sustainable coastal development and planning (Rasuly, 2010; Yanxia et al., 2013).

To understand coastline detection methods, it is first necessary to know the definition of coastline. Both term coastline and shoreline are understood as boundary lines between water and land. The term coastline is generally used to describe the approximate boundaries at relatively large spatial scales while the shoreline is used to represent the precise location of the boundary between land and water. The main difference between shore and coast is one of scale. Shores are relatively narrow strips of land adjacent to water bodies, whereas, coasts generally depict relatively broad bands of land adjacent to water bodies (Oertel, 2005). The coastline is flexible depending on sea level, swell, tides, and near-shore currents. To monitor coastal change, a shoreline indicator is required. Because of the dynamic nature of this borderline, the chosen indicator needs to take into account the shoreline in a spatiotemporal sense and must consider the dependency of this variability on the time scale (Seynabou et al., 2019).

Remote sensing data has been used in coastal applications for decades. From 1927 to 1980, aerial photographs were known as the sole source for coastal mapping. However, collecting, rectifying, analyzing, and transferring the information from photographs to map are costly and time-consuming. From 1972 the Landsat and other remote sensing satellites provide digital imagery in infrared spectral bands where the land-water interface is well defined (Alesheikh, et al., 2007). Landsat and SPOT are considered the most widely used. The multispectral capabilities and multi-temporal of these data allow observation and measurement of biophysical characteristics of coastal habitats as well as to detect the changes of the coastal zone over time (Wang and Moskovits, 2001). Landsat and SPOT imageries have been applied in inventory mapping, change detection, and management of mangrove forests (Aurélie et al., 2015), and to map seagrass coverage (Mitchell et al., 2012; Bakirman et al., 2016). The monitoring coastline change can be determined directly by field measurement methods. Boak, E. H, and Turner, I. L (2005) gave out a series of possible methods to define the coastline such as using the aerial photo, beach survey, and remote sensing data. Since manual delineation is labor-intensive and often subjective, some automatic coastline extraction methods have been proposed. Using drones is an effective method that has been applied in studies to determine shoreline changes (Apostolos et al., 2016). Accordingly, data collected from drone-attached cameras will provide information about the shoreline changes and other daily fluctuations due to tidal current. A ground processing station will receive information from drones and analyze it. Technological developments, especially remote sensing, have allowed the use of satellite imagery in coastline change analysis. Satellite data can provide valuable information about the erosion-accretion process, development of vegetation cover in the coastal zone as well as the change in coastal structures. So, they have been applied in researches to evaluate coastline changes from medium resolution satellite images such as Landsat (Mohamed et al., 2020; Davood et al., 2018; Aliakbar et al., 2010) or using SPOT (Putu et al., 2018) to high-resolution satellite images such as IKONOS, Quickbird (Ford and IMurray, 2013). In addition to the above shoreline detection from image processing, methods based on digital elevation models have also been explored (Liu et al., 2017).

In Vietnam, using multi-time satellite image data in monitoring coastline change was presented in many recent researches. Coastline mapping can be defined by direct field measurement, aerial photography analysis, and remote sensing analysis by using satellite imagery (Bui Thi Kien Trinh and Nguyen Manh Cuong, 2018). In another research, Tran Dinh Lan et al. (2005) used SPOT, ASTER, Landsat, RADASAT combined with documents from fieldwork in assessing coastline erosion at Tam Giang and Cau Hai lagoons. In this study, the color composite method is applied to highlight the water-land boundary and given the threshold method to identify the water body. This method is quite simple, but the results are reliable and verified in the field. Dao Dinh Cham et al. (2013) analyzed the change of coastal mudflats at Cua Day, located between Nam Dinh province and Ninh Binh province in the north of Vietnam, from 1966 to 2011 by using combined Landsat and SPOT. They applied the image ratio method proposed by Alesheikh et al. (2007) to extract water-land information and mapped the changes of coastal mudflats in Cua Day from 1966 to 2011 using GIS. This study pointed out the importance of shoreline change monitoring in protecting the coastal ecological environment under the impact of climate change. Although the results from these studies are more positive, the cost of high-resolution images has always been a barrier to research, especially for developing countries. In recent years, along with the development of science and technology, remote sensing has a dramatic development by the introduction of a series of new satellite generations with outstanding features. The integration of GIS (Geographic Information Systems) and Remote Sensing offers a powerful tool in research categories of Earth science. In which, Sentinel mission developed by ESA (European Space Agency) is considered as one of the typical examples. Sentinel 2A/B launched in 2015 and 2017 has many outstanding features to meet the needs of research and environmental resource management. Sentinel 2A/B contains many advantages such as good spatial resolution (10 meters for four visible and near-infrared bands), short revisit time (every 5 days), high spectral resolution (13 spectral bands) and covering large areas (290 km field of view), hence it can provide diverse and continuous information of the study area (Robert Chastain, 2019). Sentinel 2 data is the preferred choice of many studies in recent years, but it has not been commonly applied yet in research related to monitoring natural resources and the environment in Vietnam. Some typical studies in recent years such as Tran Thi Phuong et al., 2019, Binh Thai Pham and Indra Prakash., 2018, Bui Thi Kien Trinh, and Nguyen Manh Cuong., 2018.

The objective of this study is to evaluate the capability of Sentinel 2A and Landsat 8 data in monitoring coastline change from 1999 to 2018 at Cam Pha city, Quang Ninh province. The specific objectives were to:

(1) map the coastline change in the study area between 1999 and 2018, (2) compare the performance of Landsat 8 and Sentinel-2A in mapping coastline changes, and (3) explore possible causes and propose solutions to minimize the risks caused by the changes in the coastline.

2. Study area

The study area consists of the entire coastline of Cam Pha city, Quang Ninh province with a length of over 50 km (Fig. 1). It lies between 20058'-21012'N latitudes, 107°10'-107°23'E longitudes. The topography is divided into three parts (1) the hill and mountains cover 70% of the total area with an average elevation of 150 m to 250 m, located in the North and Northeast. There are some relatively flat valleys alternating between the mountains (2) the coastal plain lies in the South with an average height of 0.5 to 5 m and (3) the islands and archipelagos in the Gulf of Tonkin.

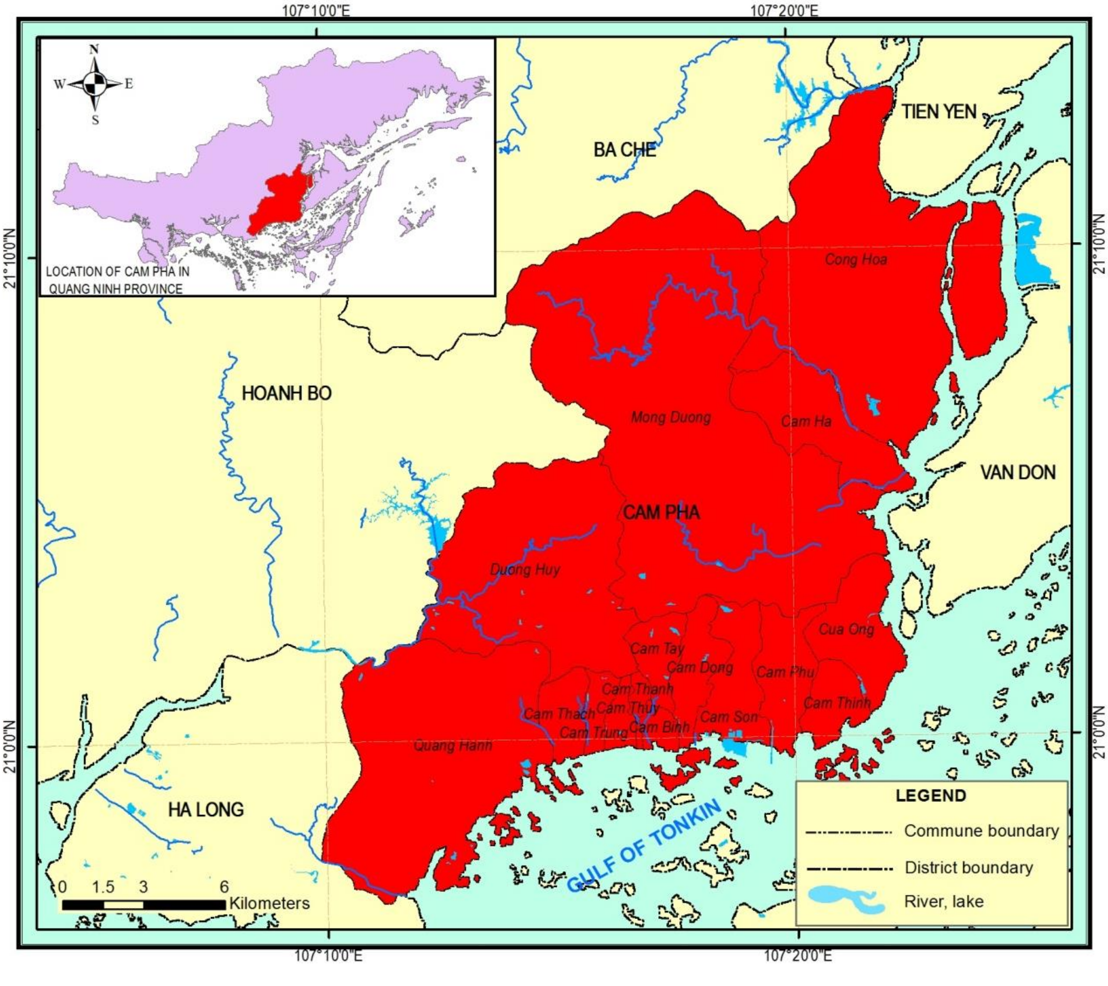

Figure 1. Location of the study area

2.1. Geology, climate, and hydrology

Cam Pha has a rather complicated geological structure with many faults of the Bac Son formation. Tectonic movement causes cracks, associating with humidity and run-off, create grooves and different forms of terrain. The coast is associated with long and narrow open sandy beaches, barrier spits, estuaries, and coastal ecosystems, such as mangroves, coastal forests, and aquaculture ponds as well as major and minor industries. It is controlled and hindered by natural causes - estuarine mouths, rock exposures, source of beach material, littoral drift, wave refraction, etc. and human activities. The recent alluvium deposits occur along the riverbanks and seacoast. Karst processes are the typical geological activity in the South of the study area (Nguyen Thi Kim Hoan, 1985).

The study area experiences the tropical monsoon climate and is directly influenced by the marine with an average temperature of 23,5°C. The average annual rainfall is about 2144 mm, of which about 86% is received from May to October and the remainder is given from November to April. The average humidity is about 85% and depends on the rainfall, elevation and divided by seasons (Nguyen Van Cu and Dinh Van Huy, 1999). The river network is quite dense, with a large water flow. However, due to the divided catchment topography, most of them are small, short, and steep rivers. The coast of Cam Pha city has many breakwater bays which limit the influence of marine factors such as tide, waves. The tides are diurnal tides with a mean tidal range of 2 to 3 m and a maximum of 4 m (Pham Quang Son and Nguyen Van Cu, 1990).

2.2. Human activities

The area is densely populated with 155.800 people and population density is 463 people/sq km in 2019 (Quang Ninh Statistical Yearbook). Population concentrated in coastal areas and associated with fishing activities. The coast has been experiencing increased anthropogenic pressures such as uncontrolled and illegal urban development, industrial runoff, sewage discharge, and seashore reclamation. In recent years, the development of Cam Pha has been based on industry and services, especially the coal industry and marine transportation (Dang Thi Ngoc, 2011). This generates artificial topographies with mining pits and disposal sites. As a result, land subsidence has occurred, affecting groundwater and surface water in some areas in the city. The erosion - accretion process and coastal water pollution caused by human exploitation activities are also causing negative impacts on the environment here. In this context, the detection and monitoring of coastline change are essentially needed in order to identify areas that require further investigation, management, and protection.

3. Methodology

3.1. Data used

Landsat 8 and Sentinel 2A were used to determine the boundary between land and sea in the study area. Landsat 8 was freely collected from the website of The United States Geological Survey (USGS) https://earthexplorer.usgs.gov/. This satellite was launch in 2013, carried Operational Land Imager (OLI) and the Thermal Infrared Sensor (TIRS) with a spatial resolution of 30 m (8 bands), 15 m (1 band), and 100 m (2 bands). The revisit time of Landsat 8 is 16 days. The second satellite data is Sentinel 2A level 1C which was launched relatively recently (in 2015) and freely downloaded from the website of the European Space Agency (ESA) https://scihub.copernicus.eu/. Sensor Multi-Spectral Instrument (MSI) covering 13 spectral bands (443-2190 nm), with a swath width of 290 km and a spatial resolution of 10 m (four visible and near-infrared bands), 20 m (six red edge and shortwave infrared bands) and 60 m (three atmospheric correction bands). The detailed information for the satellite images is presented in Table 1. Tides cause rapid sea-level variations. The tidal regime in the study area is relatively simple with the diurnal regime. The tidal information was looked up from the tide table. Since the selected images were acquired in good weather conditions (calm sea), the influence of meteorological tide was neglected. The time-series satellite dataset also was collected at a similar time to eliminate the error by tidal levels. Besides, to avoid cloud and unwanted shade-free imagery, the images were selected at times with the cleanest sky in November. Coastline map extracted from topographic map system at the scale of 1:50,000 in 1999 by Quang Ninh Department of Natural Resources and Environment 1999 was used as a reference of the same mask to identify the erosion-accretion location at the Cam Pha coastline from 1999 to 2018. The overall methodology of this study is briefly presented in Fig. 2.

Table 1. Details of the satellite dataset used in this study

Sensors	Path/Row	Acquisition Data	Acquired Time	Tide height (m)	Condition
OLI/TIRS	126/45	23 November 2018	03:17:10	3.2 m	Rising
MSI	126/45	02 November 2018	03:27:32	1.7m	Rising

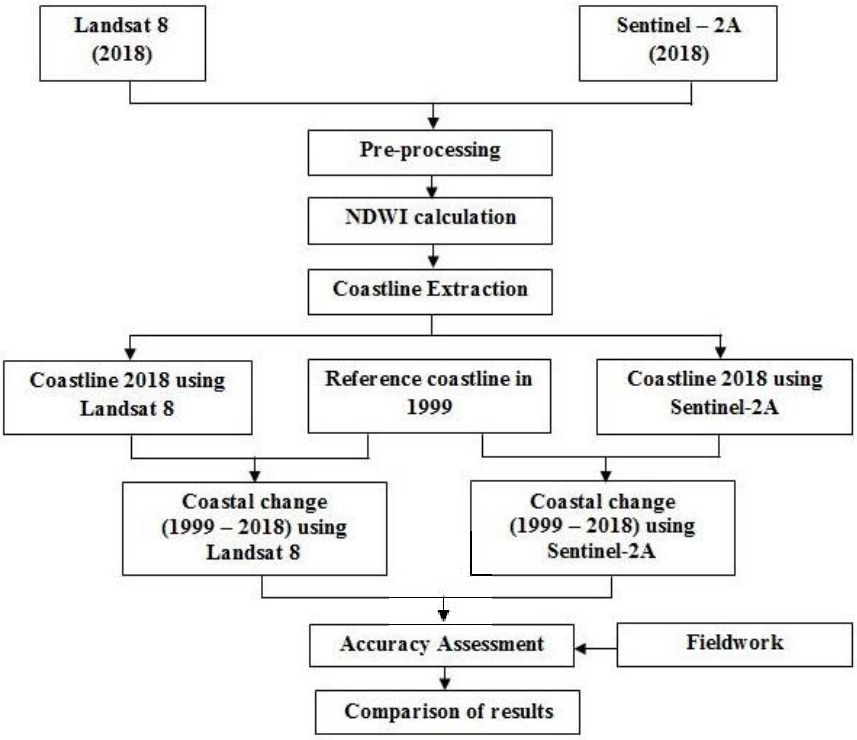

Figure 2. Methodological flow chart

3.2. Preprocessing

This process was performed on images including geometric and radiometric corrections.

- *Geometric correction*:

All used images used should be checked and agreed about geometry before processing. Although Landsat 8 and Sentinel 2A were collected from different sensors, both were already geo-corrected before downloading, and it was Universal Transverse Mercator (UTM) WGS- 84 Datum, Zone 48 in this case.

- *Atmospheric correction:*

Atmospheric correction is an essential step to eliminate negative effects on the accuracy of results caused by the atmosphere. For Landsat 8, this process includes two steps: (1) converting digital numbers (DNs) into radiance value and (2) standardizing the effect of the atmosphere. For the Sentinel, Sentinel - 2A level 1C is used in this study. It already provides the Top-Of-Atmosphere (TOA) reflectance. So, we need to calculate Bottom Of Atmosphere (BOA) reflectance from Top Of Atmosphere (TOA) reflectance with the support of SNAP software.

The subset steps were also carried out to reduce the size of the scene to include only the study area and speed up processing. All these steps were processed with the support of ENVI 5.2 and ArcGIS 10.4 software. These are copyright software invested by TRIG (Teaching Research Innovation Grant) project of Hanoi National University of Education.

3.3. NDWI calculation and coastline extraction

Normalized Difference Water Index (NDWI) is an important index related to liquid water and is calculated by two different methods. The first method is used to monitor changes in the water content of leaves proposed by Gao in 1996. The second one is used to monitor changes related to water content in water bodies defined by McFeeters in 1996. In some locations of the study area occupied by mangrove forest and other kinds of vegetation or turbid water areas at the estuary positions, the boundary between the sea the land is disturbed affecting the accuracy of the study results. To overcome this issue, NDWI was calculated based on Gao's equation to make discrimination between real vegetated land and the tidal zone or turbid water by using near-infrared (NIR) and short-wave infrared (SWIR) wavelengths (equation 1). In this equation, the NIR reflectance is very sensitive with leaf internal structure while the SWIR band reflects strongly on changes in both the vegetation water content and the spongy mesophyll structure in vegetation canopies. The combination of the NIR with the SWIR removes variations induced by leaf internal structure and leaf dry matter content, improving the accuracy in retrieving the vegetation water content (Ceccato et al., 2001). The NDWI product is varied between -1 to +1, depending on the leaf water content but also on the vegetation type and cover. High values of NDWI correspond to high vegetation water content and high vegetation fraction cover and the opposite, low vegetation water content gives low values of NDWI. In the next step, a semi-automatic technique was applied to create the coastline shape based on equation (2) (Claire et al., 2012). The bands were described in table 2. To extract the coastline shape from the satellite image, it is necessary to classify the objects in the image into two main categories: land and water. Therefore, in the next step, after highlighting the difference between land and water by equations (1) and (2), the author digitizes the coastline in this study by ArcGIS software. Although this method is more manual and takes longer, it is more accurate. Furthermore, at a complex topographic surface area, it can be adjusted based on reference material to ensure accuracy.

Table 2. The bands used to extract the coastline

Landsat 8				Sentinel 2A		
Bands		Wavelength (micrometers)	Resolution (m)	Bands	Wavelength (micrometers)	Resolution (m)
Green band	Band 3	0.53–0.59	30	Band 3	0.537–0.582	10
NIR	Band 5	0.85–0.88	30	Band 8	0.767–0.908	10
SWIR	Band 6	1.57–1.65	30	Band 11	1.539–1.681	20

NDWI = (NIR–SWIR)/(NIR+SWIR) (1)

Coastline = (G/NIR)×(G/SWIR)+NDWI (2)

Where: NIR: Near-Infrared band;

SWIR: Short-Ware Infrared band;

G: Green band.

3.4. Comparison of classification results

In order to compare and evaluate the classification results between those of the Landsat 8 and Sentinel-2A, a spatial analysis was performed in ArcGIS. The overlay process between reference data in 1999 and coastline extracted in 2018 from Landsat 8 and Sentinel 2A was carried out respectively.

As a result, the spatial difference after overlaying between the data of the two periods reflects the change detection from 1999 to 2018. In the next step, coastline and reference points extracted from Google Earth is used to evaluate the accuracy and make comparative comments. Because it is impossible to use Google Earth images as base maps directly with ArcGIS software, the scope of study area location on Google Earth was bounded by placemark points and saved as the image to open in ArcGIS software. These placemark points are used as ground control points to define the spatial information of the image. The time slider tool in Google Earth helps to select satellite images at the same time as data in the study (November 2018). In the next step, the image has defined the latitude and longitude coordinates by using georeferencing function in ArcMap. Similarly, 50 reference points with attribute information are extracted from Google Earth to compare with results from image interpretation.

4. Results

After pre-processing, the Sentinel2A and Landsat 8 were used to compute the NDWI index and then vectorized to create the coastline in 2018. According to the calculation results, there is a significant difference between obtained NDWI from Landsat 8 and Sentinel 2A. As a result, the value range of NDWI from Landsat 8 was scaled from -0.293282 to 0.550463 (Fig. 3a) while it corresponded -0.762057 to 0.975309 with Sentinel 2A (Fig. 3b). The contrast was shown more clearly in the Sentinel 2A image. In the next step, the areas of erosion and accretion were assessed and interpreted by overlaying the 1999 and 2018 coastline maps. The analysis results from both images (Landsat 8 and Sentinel 2A) showed that there was a significant fluctuation in this phase. Accretion is the dominant process during the period 1999-2018. This process took place quite strongly on the East and Southeast coast while the erosion process only occurred with small areas at scattered points in the North of the study area.

Consequently, the coastline change at Cam Pha from 1999 to 2018 using Landsat 8 was described in Fig. 4a. As a result, accretion is a typical process with areas at 1144.9 ha, distributed mainly in communes such as Cong Hoa, Quang Hanh, Mong Duong, Cua Ong. The largest area of accretion was Quang Hanh (290.5 ha), followed by Cong Hoa (255.3 ha) and Mong Duong (134.4 ha). Erosion occurs in some communes such as Cong Hoa, Quang Hanh, Cua Ong, and Cam Trung (Fig. 4b). In which, the largest area of erosion was Cong Hoa (240.2 ha), the second position was Cua Ong (30.3 ha). According to the results of interpretation from the Sentinel 2A image, accretion is also a common process in the period 1999-2018 in the study area with a total area of 1442.1 ha (Fig. 5a). For instance, this process occurs in most coastal communes, such as Cong Hoa (440.8 ha), Quang Hanh (315.5 ha), Mong Duong (157.0 ha) (Table 3). In contrast, the erosion process only works in a small area with a total area of 11.8 ha and distributed in communes such as Cam Trung, Cong Hoa, Quang Hanh (Fig. 5b). As the results, it is possible to divide the studied coast section into three zones with different properties (Fig. 6):

Zone 1: located in the north of Cong Hoa commune, with a length of about 15 km. The interpretation result from both Landsat 8 and Sentinel images showed that erosion is the dominant process while the accretion process is relatively slow (Fig. 7). In addition to natural causes such as shoreline direction, wave action, and tides, the main cause of erosion is human production activities such as sand mining and construction materials. In agriculture, the destruction of mangroves for aquaculture has severely deformed the coastline in this area.

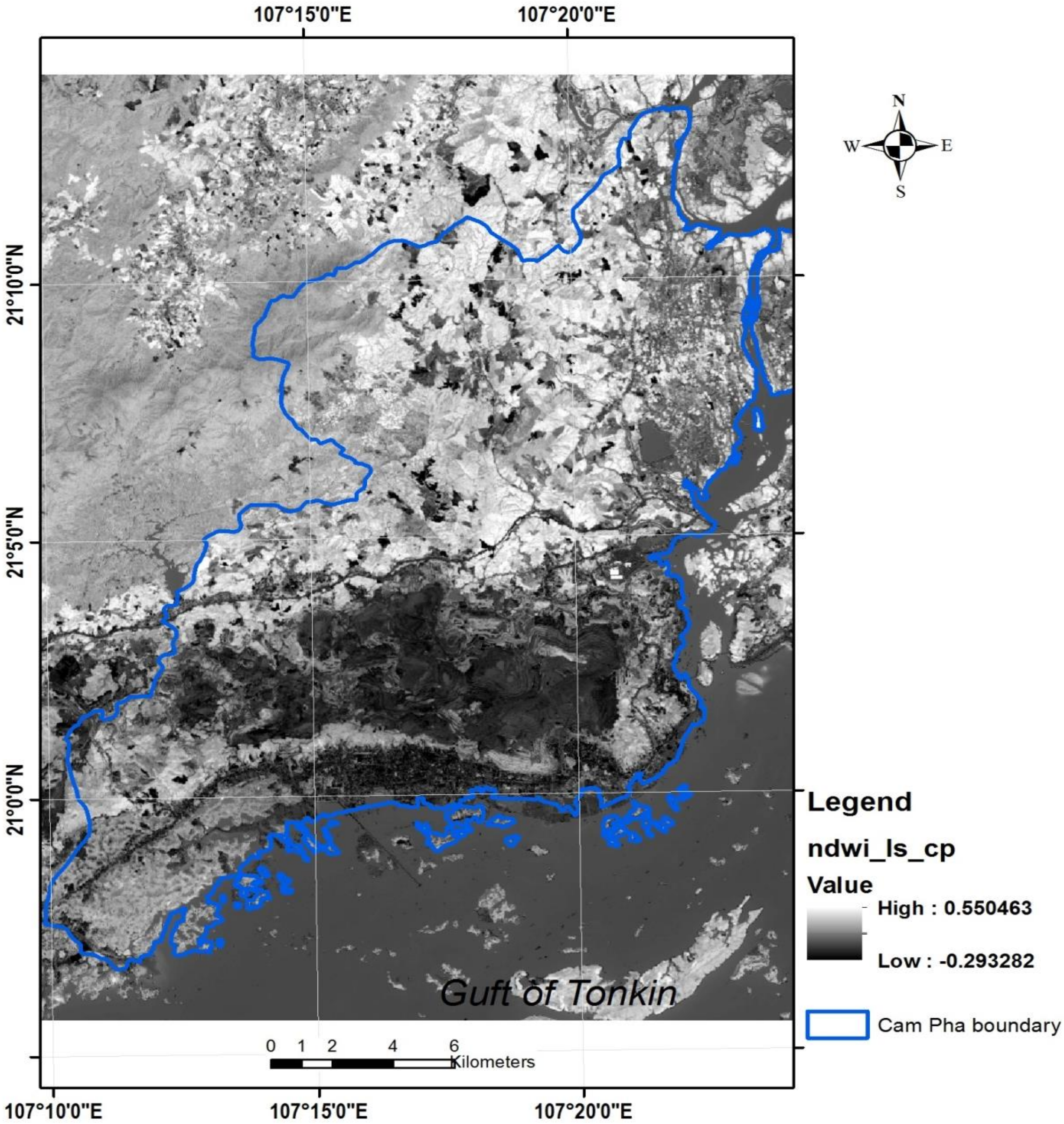

Figure 3a. NDWI value from Landsat 8

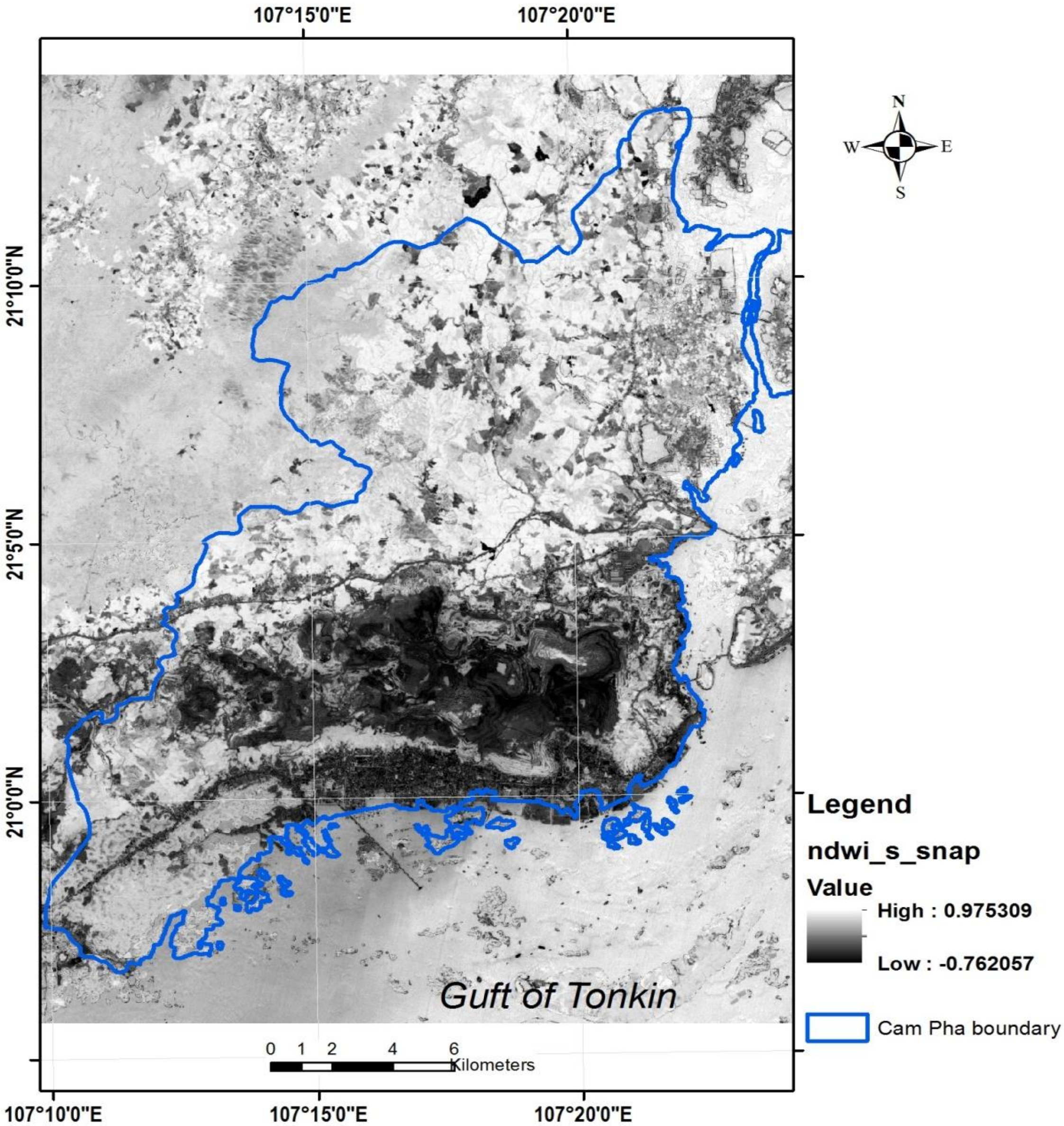

Figure 3b. NDWI value from Sentinel-2A

Zone 2: connecting zone 1 and extending from the coastline of Cam Ha to Cam Thach, about 23 km in length, the accretion process dominates completely (Fig. 7). The reason is leveling from production activities especially being coal production. The amount of coal mining materials moved to the coastal area increases the rate of sedimentation on average about 0.25 mm/year (12.5% of the total). The area in the middle of the bay has an average sedimentation rate of 1-2 mm/year and the outer edge of the bay has a common sedimentation rate of about 1 mm/year. In the areas close to the coastline, the sedimentation rate is the highest, reaching locally 6-7 mm/year. The removal of a volume of soil and rock many times larger than the volume of coal mining has caused a dramatic change in the topographic landscape and surrounding areas.

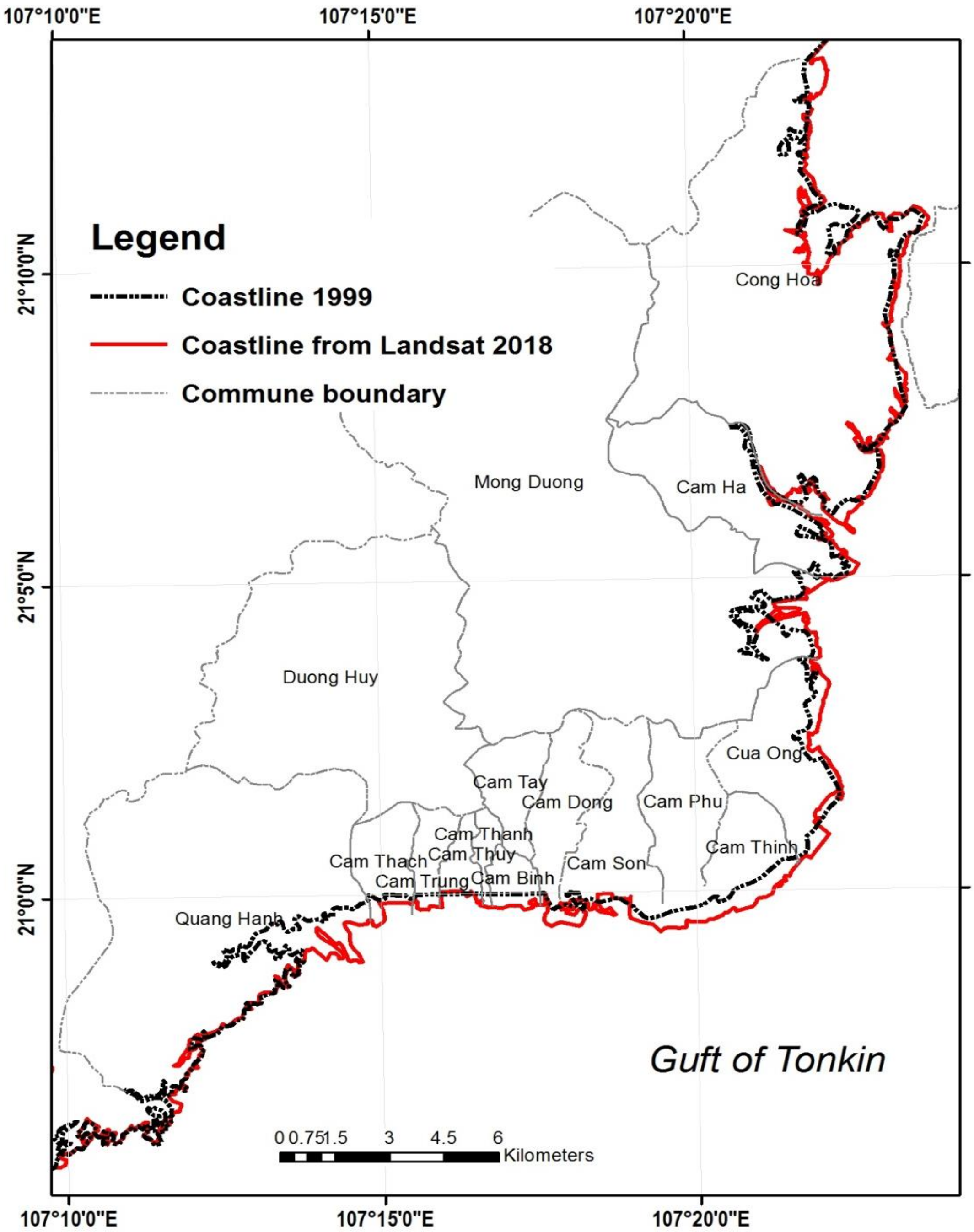

Figure 4a. Coastline changes from 1999-2018 using Landsat 8

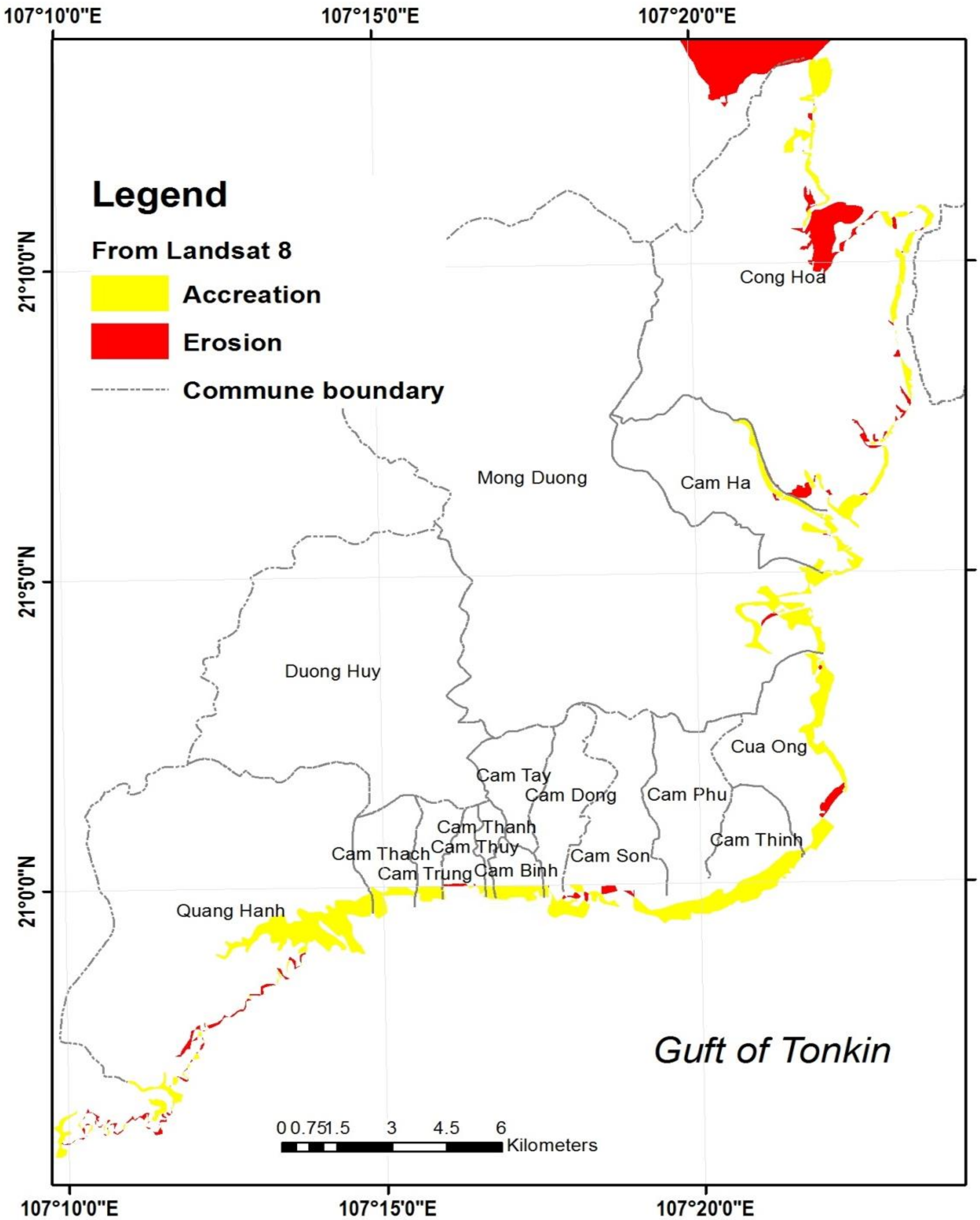

Figure 4b. The Erosion-Accretion situation from 1999-2018 using Landsat 8

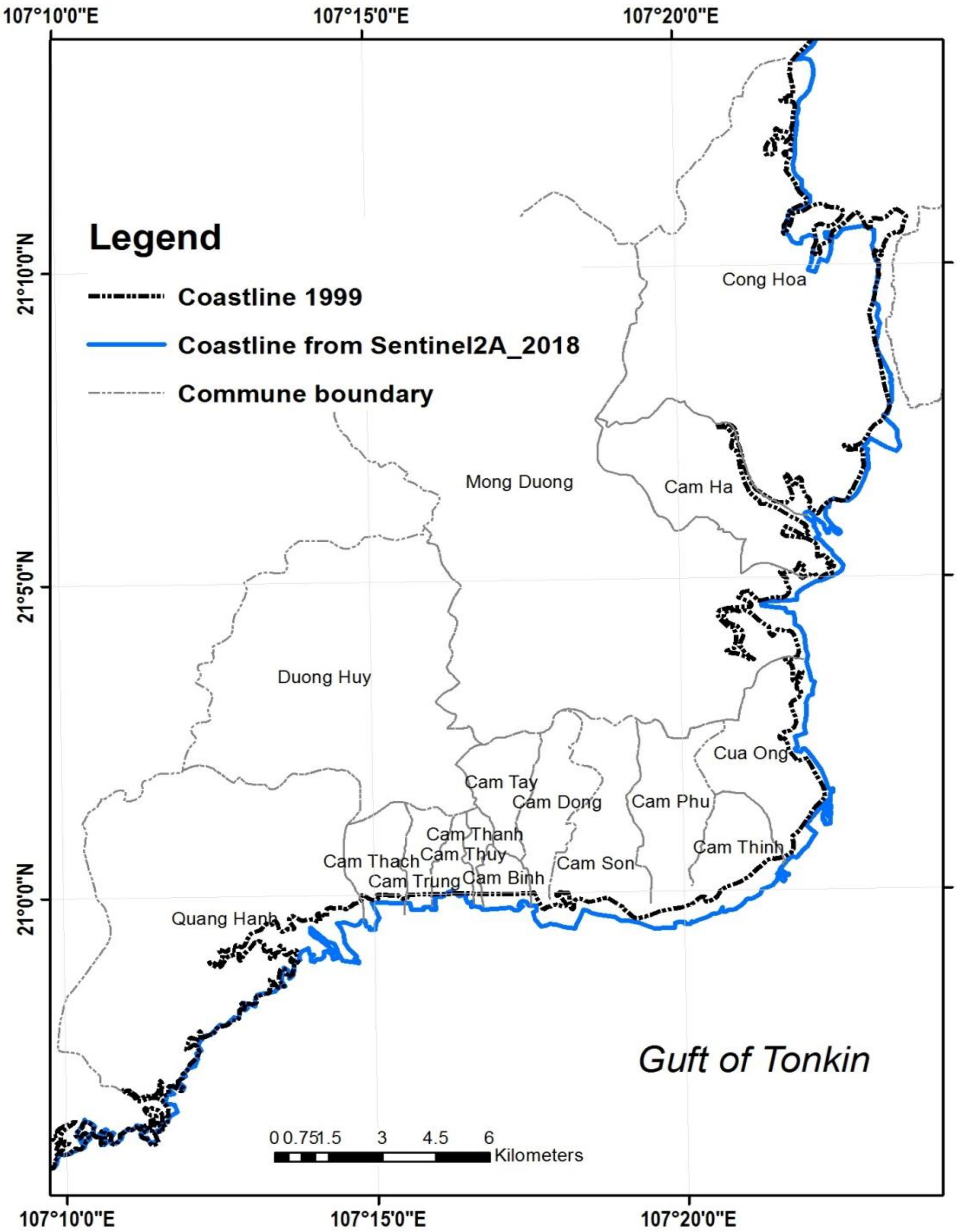

Figure 5a. Coastline changes from 1999-2018 using Sentinel 2A

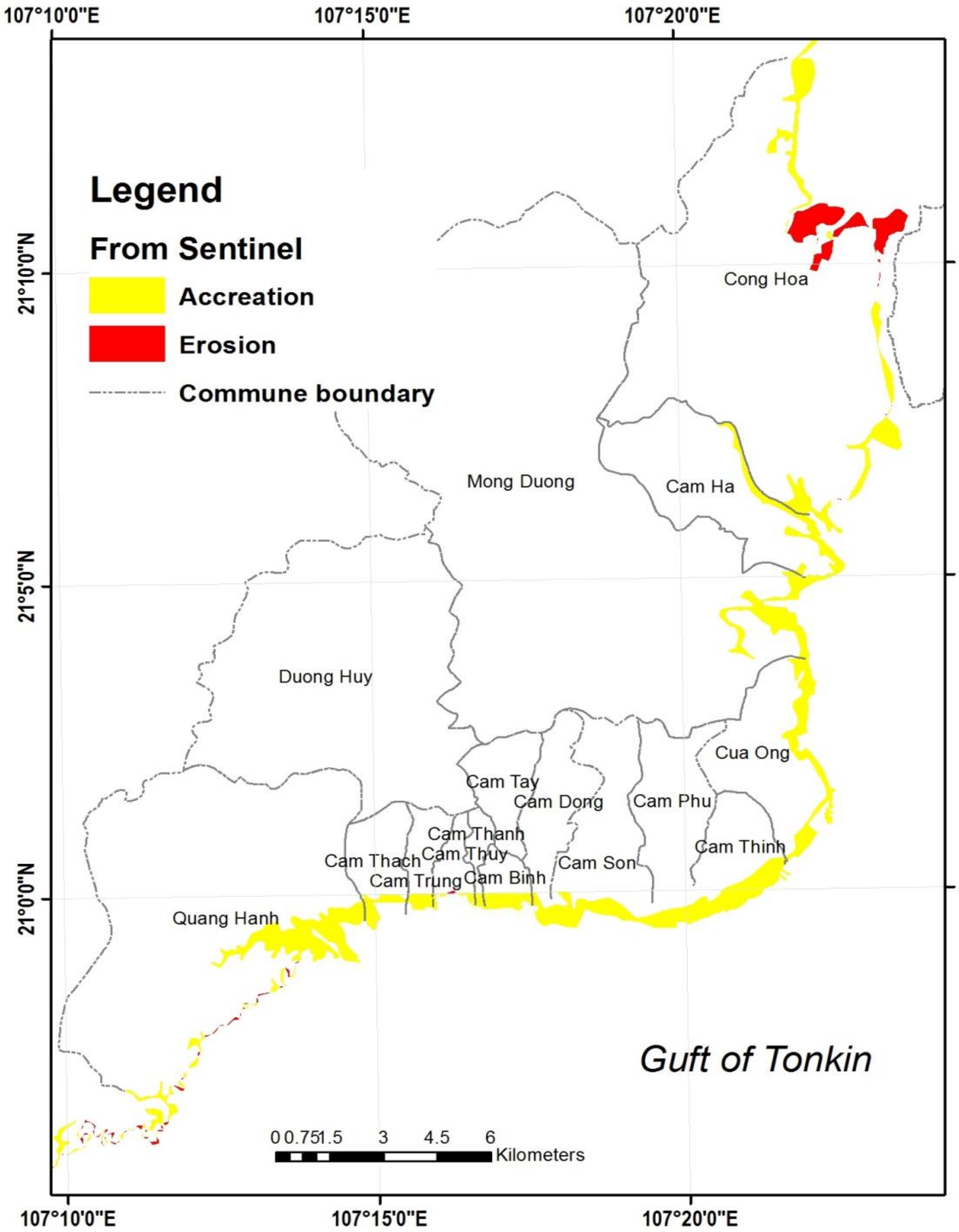

Figure 5b. The Erosion-Accretion situation from 1999-2018 using Sentinel 2A

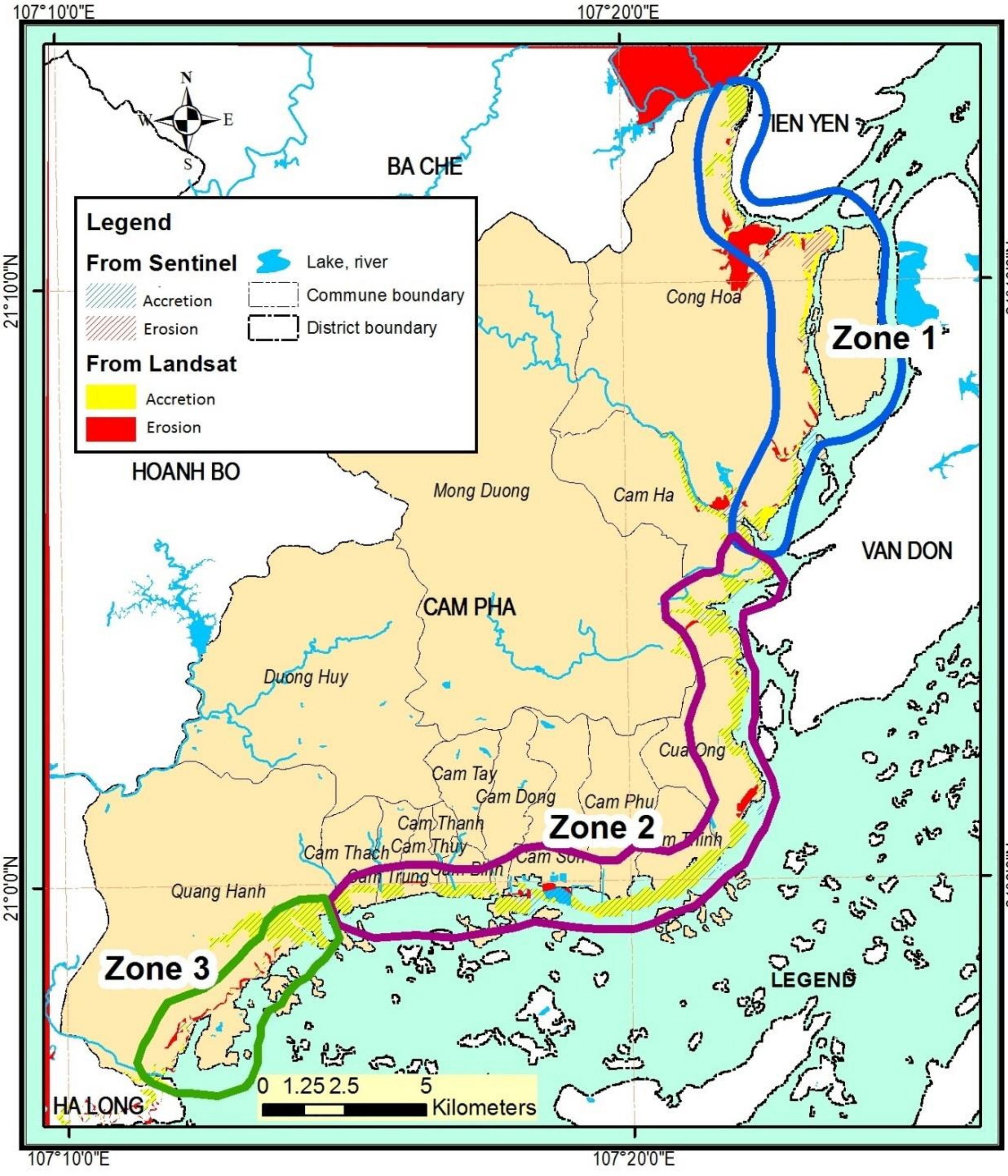

Figure 6. Zoning Erosion - Accretion areas of Cam Pha coastline

Zone 3: It covers the entire coast of Quang Hanh, about 12 km in length, this area takes place alternating the erosion and accretion process (Fig. 7). The accretion has caused by leveling and material accumulation from the flow. Erosion is weak, mainly due to natural factors.

There is a difference between the results from Landsat 8 image and Sentinel 2A. Accordingly, the area of coastal erosion using the Landsat 8 image is greater than that of the Sentinel 2A image while the accretion area is the opposite, although the accretion process is still the dominant process. The results of the comparison between Sentinel 2A and Landsat 8 images are described in Fig. 8. Accordingly, the differences between the lines show changes in the coastline in the study area. Blackline (1999) is used as a reference benchmark, the red line is the results interpreted from Landsat 8 depicting the coastline in 2018 and the blue line represents coastline in 2018 from the Sentinel 2A image. The detailed differences are presented in Fig. 9 and Fig. 10. Accordingly, the area with the biggest difference according to interpretation results from the satellite images concludes communes: Cong Hoa, Quang Hanh, and Cua Ong communes.

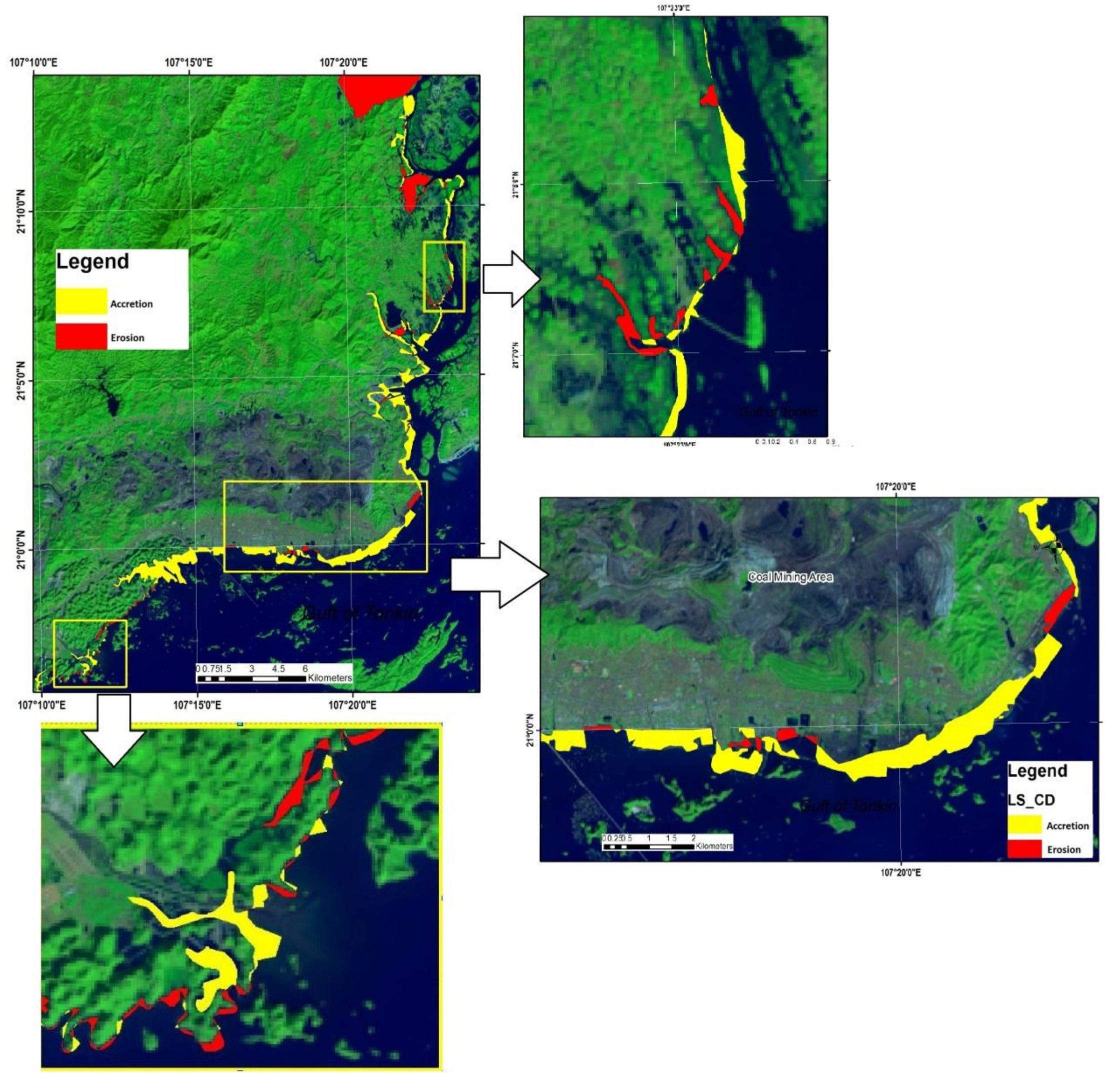

Figure 7. Coastal change in detail from 1999-2018

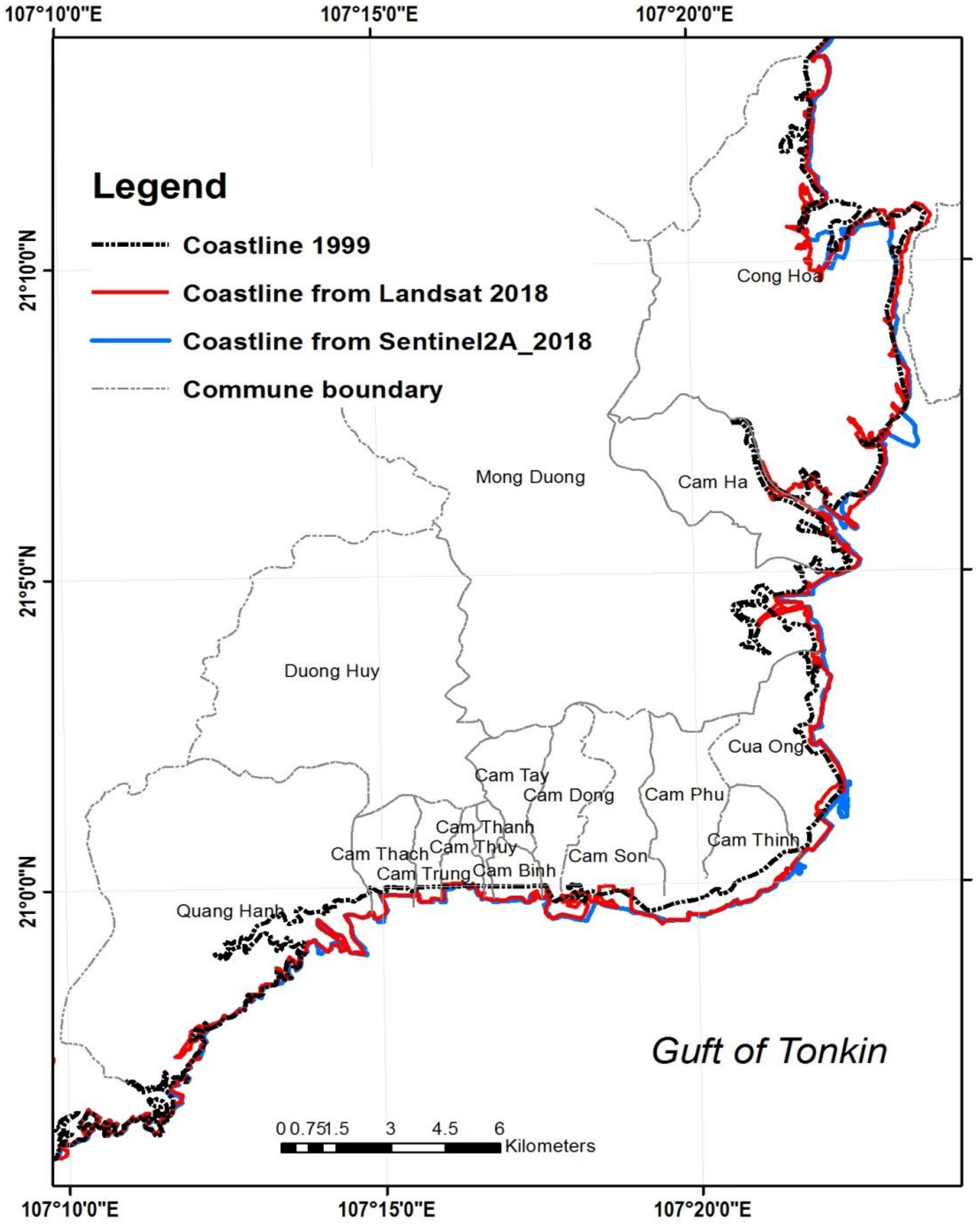

Figure 8. Difference about coastline change from 1999-2018 using Landsat 8 and Sentinel 2A

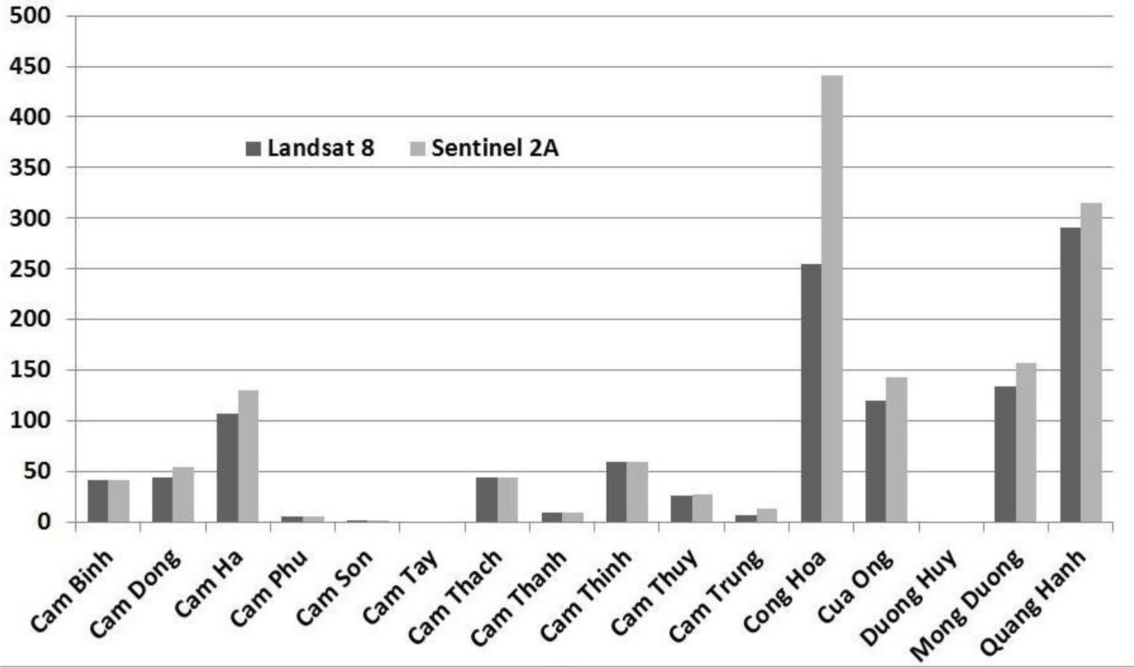

Figure 9. Difference about accretion area among communes from 1999 to 2018

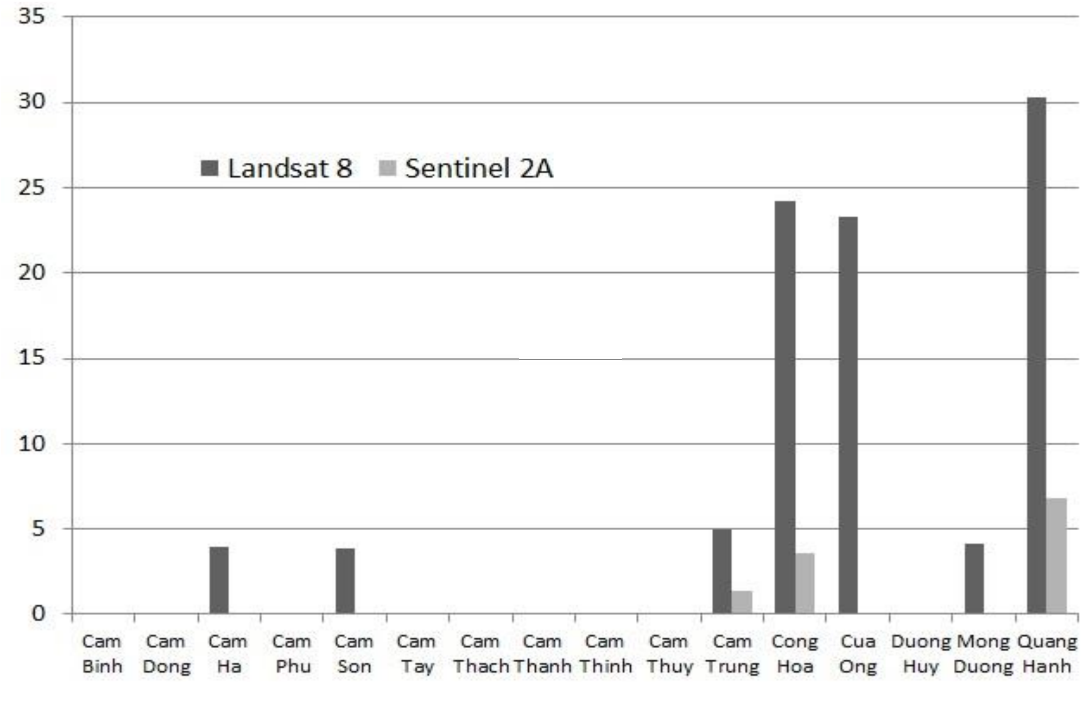

Figure 10. Difference about erosion area among communes from 1999 to 2018

To verify the results of the study, the reference points from Google Earth maps taken November 2018 were included to assess the accuracy. The ratio between the number of coastline points/ 50 reference points from two images is used to compare the accuracy of the result (Fig. 11). As the result, the overall classification accuracy of Sentinel 2A imagery (95.0%) was slightly higher than that of Landsat 8 (87.5%). The difference could be explained by the improved ability to classify small geographic variation across the land-water boundary when using higher spatial resolution data and multi-spectral information from the Sentinel 2A image.

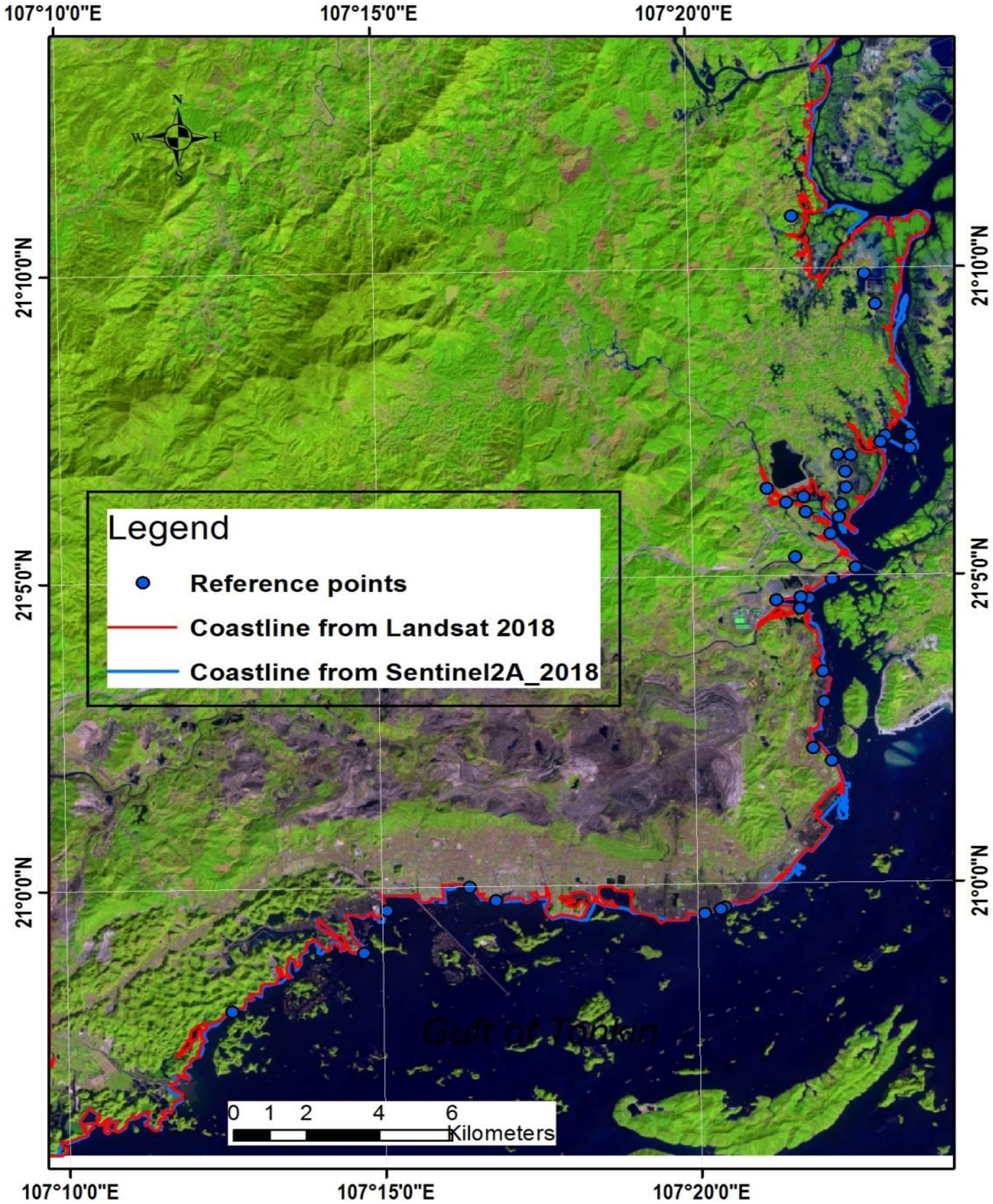

Figure 11. Location of reference points

Compared with previous works, there is consistency in research results. Nguyen Van Thao et al. in 2013 used Landsat TM was taken in 1990, AVNIR-2 image taken in 2008, and topographic map at scale 1:50.000 to analyze the ecological change of the coastline. Consequently, the erosion process took place at some points in the area of Quang Ninh province, including Cam Pha due to aquaculture, leveling, and fishing. Fieldwork was also carried out by the authors to verify the research results.

According to research from the doctoral thesis of Nguyen Van Thao in 2015, the change took place in the 66 sections of the coast in Quang Ninh, including Cam Pha coastline, 01 segment by natural erosion, 03 segments by natural accretion, 14 segments of accretion due to aquaculture products, 20 segments of accretion due to expansion of the mangrove forest and 28 segments of accretion due to leveling from 1990 to 2013. As a result, the Cam Pha coastline was dominated by the accretion process due to mangrove development in the north and by leveling and urban construction in the center and south.

In another research by Tran Quoc Cuong in 2004 about the impact of open coal mining on coastal topography in Cam Pha – Cua Ong area (Quang Ninh) from 1993 to 2001 by using an aerial image, Landsat image, and field data. The result showed that the landfill filled up the estuary and formed an artificial lake and it was expanded 450 m to the west and southwest of the coastline. Besides, the wave activity makes it easier for coastal accumulation, especially where the topography is perpendicular to the shore such as Cam Pha. This conclusion completely coincides with the research results of the research.

In summary, the analysis results of coastline changes in Cam Pha from 1999 to 2018 are reliable, consistent with previous studies.

5. Discussions

Coastal erosion - accretion is a complex natural process and interaction of many factors. Erosion and accretion are a typical hazard that usually occurs along the Cam Pha coastline. Based on the analysis of temporal coastline change, it can be seen that the changing of the coastline is caused by a combination of natural evolution, human impacts, and climate change. In which, human activities are the most powerful factor. Therefore, the assessment of the cause of this process must be considered in such aspects as sediment transport under the influence of waves, wind, and tidal currents; human activities in the scope along the coast, on river basins, in space as well as in time (Nguyen Thi Kim Hoan, 1985). Because the coastline of Cam Pha is made up of terrigenous formations, limestone and is located inside the bay where the wave regime is very weak, accretion - erosion in Cam Pha is mainly due to human impacts.

In particular, human activities such as leveling and expanding urban areas, reclamation for coastal aquaculture, agricultural reclamation, construction of industrial parks, coastal tourism, and seaports are the main causes of the accretion process in the study area (typical as commercial tourism project Green Dragon City, Quang Hong urban area). Especially the rapid development of the coal industry in Cam Pha has promoted the process of land leveling and expansion, but it also harms the coastal ecological environment (Cam Pha Thermal Power Plant). The less eroded areas are mainly along erosion valleys or currents. Due to the geological structure, the weathering of limestone is quite common, causing erosion according to natural laws.

The produced “reference data” in 1999 was used for evaluating the classification performance in each of the two cases of employing satellite imagery of 2018.

According to Decision No.178/1998/QĐ-ĐC of the General Department of Land Administration, the area where land meets the sea or ocean in topography maps is defined as the coastline and it is determined as the average highest water level for many years formed by water activities in a long history. In Vietnam, there is no standard relating to the measurement of the length of the coastline. The main method when calculating the length of the coastline is that we have to divide the coastline into equal successive straight segments. The smaller the length of the sections is, the greater the total length of the coastline is the shoreline due to the straight lines getting closer to the actual shoreline, which means higher accuracy (Bui Quang Dung and Uong Dinh Khanh, 2016). However, errors could occur due to the complexity of coastal shape (lagoons, estuaries, bay, etc.) and inconsistency in the measurement process. This method also requires a lot of time and effort, but it provides high accuracy and can be used as reference data with other data. In this study, satellite images (Landsat 8 and Sentinel-2A were used to interpret the coastline. This applied method will save time, money, and effort. However, it could be affected by two sources of errors, namely errors caused by the data sources and errors caused by the interpretation and the measurements. As for the interpretation, errors could occur due to seasonal changes that result in the movement of the dry/wet line. Besides, working with different resolutions/characteristics could lead to a misinterpretation of the coastline position. In this case, Sentinel-2A has a better resolution than Landsat 8, so it is expected to bring more accurate results.

In addition, the tidal height also partly affects the research results. Accordingly, the tidal height at the time taken Landsat image was 3.2 m which is much higher than that at the time taken Sentinel image (1.7 m). Therefore, the consideration of tidal factors is very necessary. However, it was eliminated in this study, which caused limitations in the research results.

Generally, the combined use of satellite images of Landsat 8, Sentinel 2A, and fieldwork data provided reliable results in evaluating coastline change in the study area. It also contributes to the orientation for using a combination of satellite images to effectively take advantage of each type in the study.

6. Conclusions

The aim of this work is to evaluate the coastline change of Cam Pha city for a period of 19 years (1999-2018) by using satellite images. The results showed that the accretion process is prevailing and happening strongly in the South and Southeast in the study area. Accordingly, possible factors influencing this process are caused mainly by human activities. The natural process (tropical typhoons, alongshore currents, and wave and tidal dynamics) promote erosion at the coastline at some positions.

The research results have shown the capability of Landsat 8 and Sentinel-2A in monitoring coastline change. Although the classification of the two images resulted in close mapping accuracies, the use of Sentinel 2A imagery provided slightly better classification reliability. Yet, both images showed satisfactory results in mapping shoreline changes. This comparison is to explore the advantages of each type of satellite image. The outstanding advantages of these two types of images are multi-spectral, multi-temporal, and spatial resolution improved increasingly. Recognizing the slight differences in their spectral and spatial sampling, thereby the combined use of Landsat 8 and Sentinel-2A satellite is expected to open opportunities for capturing the dynamics of coastline at rates.

Using NDWI and difference among the spectral band to highlight the boundary between the water and land worked well with Landsat 8 and Sentinel-2A images, future work involves future improvement. Accordingly, other indicators (Modified Normalized Difference Water Index - MNDWI) or other classification (Object-based classification) will also be considered to exploit to clarify the research results.

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