Comprehensive impact assessment development of the Coal field Campha in Vietnam to the coastal territory

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Abstract. Quang Ninh is a province in the North of Vietnam, located close to the sea and has high potential for economic development and conservation value with a wide variety of creatures as well as scenery. Coal mining activities in Quang Ninh province have had a great impact on the regional environment, including the coastal zone. Derived from the ability to measure and manipulate various materials and display on maps and drawings of the current status of the coast through time and space, the authors studied and processed the telecommunication data. Recruit multi-time to effectively monitor the variation of the coastal zone in general and the coast of Vietnam in particular, especially due to coal mining activities in Quang Ninh. The research results are important to provide the necessary data and information to support the planning and adjustment of coal production and exploitation in Cam Pha and Quang Ninh, Vietnam.

1. Introduction
According to the assessment report of Vietnam coal industry, the amount of industrial waste rock in recent years arise more and more. The coal industry releases hundreds of millions of cubic meters of waste rock, generate large quantities of dust, fill rivers, streams, and sea to impact on the environment around the area landscape. Besides, the development of the urban and residential are also the main reason to change the area of the coastal zone, especially are Ha Long and Cam Pha.

The Landsat remote sensing data used in this case study with a resolution of 30m and applying the method of integrating remote sensing data and GIS to determine the rate of change of land area due to the influence of mining process to the coastal area in Cam Pha, Quang Ninh. After giving a matrix to determine the purpose of land using, a correlation analysis of mantle fluctuations based on the matrix was performed using SPSS version 17.0.

Remote sensing also replaces costly and slow data collection on the ground, ensuring in the process that areas or objects are not disturbed. The exploitation of image time series from sensors with different characteristics provides new opportunities to increase the knowledge about environmental changes and to support many operational applications [1]. Orbital platforms collect and transmit data from different parts of the electromagnetic spectrum, providing researchers with useful information to monitor cities, detect changes, and to efficiently manage natural resources such as land usage and conservation [2]. Techniques developed in the present study are reproducible in many other tidal flats globally as both Landsat images, and tidal prediction is available worldwide [3]. A review of state-of-the-art retrieval methods for quantitative terrestrial bio-geophysical variable extraction using optical
remote sensing imagery is also studied and given some of algorithms and methods for this approach [4], [5], [6]. Base on that, the paper study the positive correlation between coal mining, the process of urbanization and the changing of the coastal caused by extracting processing of coal mines in Cam Pha, Vietnam.

The study of coastal changing due to mining process allows managers to see the extent of coastal ecosystem impact due to coastal zone changes, thereby benefiting long-term assessments of mining process to have timely solutions, ensure the sustainable development.

Site Study
Cam Pha is the fourth largest municipality in the province of Quang Ninh in northeastern Vietnam (Figure 1) and is home to more than 190,000 inhabitants (The 2009 Vietnam Population and Housing Census, Hanoi 2010). The town of Cam Pha is located 200 km east of Hanoi, near Bai Tu Long Bay and close to the famous Ha Long Bay (Fig. 1), a United Nations World Heritage Site [7]. Its main economic activities are industry and construction (73.5 %), trade and service (25.1 %), and agro-forestry and fishery for local consumption (1.4 %). Cam Pha, however, is principally known for its proximity to extensive coal mines, and it is home to the largest mine in Vietnam, namely the Coc Sau open-pit mine [8]. All the critical coal deposits hosted by the Lower Hon Gai Formation, an Upper Triassic sedimentary series, which consists mainly of conglomerates, sandstones, siltstones, and shales and which is up to 1,700 m thick [9], [10]. The city of Cam Pha is mainly built on Quaternary (Holocene) sand, silt, and clay, which form a narrow coastal strip.

Figure 1. (a) Map of Vietnam indicating the location of the northeastern Quang Ninh Province; (b) detailed map of the province of Quang Ninh showing the location of the Cam Pha region

The coal mining and processing industry is the primary economic sector generating income for the people. The accelerated coal mining that has driven industrialization and urbanization of the population is both a direct and indirect cause of increased coastal area.

Data collecting in this case study
The data collected for this study were image data from the Landsat satellite of Quang Ninh in 1997 and 2016 (Figure 2). Also, the study uses some other data such as 1: 50,000 Quang Ninh topographic map; Current land use map 2016 Ha Long - Cam Pha; The population statistics of Ha Long - Cam Pha in 1997, 2010, 2016.
Figure 2. the Landsat satellite of Quang Ninh in 1997 and 2016 (cut) (Source: http://glcfapp.glcf.umd.edu)

Table 1. Information on remote sensing imagery

| Year     | Spatial resolution | Spectrum          | Image channel |
|----------|--------------------|-------------------|---------------|
| 28/10/1997 | 28.5 m             | Multi-spectral images | 1,2,3,4,5,6,7 |
| 30/1/2016  | 30.0 m             | Multi-spectral images | 1,2,3,4      |

Study method and results

The process of building correlation between coastal zone change and coal production in Ha Long - Cam Pha

![Diagram showing data flow and analysis processes]

Figure 3. The process of study in coastal zone changes in Cam Pha
The software used in this case study include:
- Envi 4.3: processing and analysis of satellite images.
- ArcGIS 9.2: Analysis of changes in the land area, urban population, and shoreline changes.
- GPS - Compass alignment software: Calculate survey points using RTK measurement.

![Figure 4. Images after merging layers in 1997 and 2016](image)

**Table 2.** The matrix of land using purposes changing in 1997 and 2016 of Cam Pha - Quang Ninh

|          | 1997         | 2016         | River, lake | Forest | Sea | Coal | Vacant land | Population |
|----------|--------------|--------------|-------------|--------|-----|------|-------------|------------|
| River, lake | 1,160.28    | 0.00         | 0.00        | 638.01 | 53.55 | 273.24 |
| Forest       | 0.00        | 22,968.72   | 0.00        | 1,418.49 | 607.77 | 618.66 |
| Sea          | 0.00        | 0.00         | 10,431.18   | 645.39 | 194.94 | 0.09  |
| Coal         | 0.00        | 0.09         | 0.00        | 2,443.23 | 356.04 | 0.00  |
| Vacant land  | 0.00        | 860.94       | 0.00        | 0.00   | 504.45 | 490.14 |
| Population   | 0.00        | 0.00         | 0.00        | 0.00   | 0.00   | 4,442.22 |

To assessment of the fluctuations overlay in Cam Pha area base on the correlation matrix (Tab. 2), we used the SPSS ver.17.0 with the results shown in Table 3.

**Table 3.** Correlation coefficient of the objects between 1997 - 2016

| Objects      | Coefficient | River, lake | Forest | Sea     | Coal    | Vacant land | Population |
|--------------|-------------|-------------|--------|---------|---------|-------------|------------|
| River, lake  | Pearson Correlation | 1.00        | -0.21  | -0.20   | -0.11  | -0.46       | -0.20      |
|              | Sig. (2-tailed) | 0.69        | 0.70   | 0.83    | 0.35    | 0.71        |
|              | N            | 6.00        | 6.00   | 6.00    | 6.00    | 6.00        |
| Forest       | Pearson Correlation | -0.21       | 1.00   | -0.21   | -0.28  | 0.66        | -0.11      |
|              | Sig. (2-tailed) | 0.69        | 0.69   | 0.59    | 0.15    | 0.84        |
|              | N            | 6.00        | 6.00   | 6.00    | 6.00    | 6.00        |
| Sea          | Pearson Correlation | -0.20       | -0.21  | 1.00    | -0.11  | -0.18       | -0.28      |
|              | Sig. (2-tailed) | 0.70        | 0.69   | 0.83    | 0.73    | 0.60        |
In Table 3 we see the correlation of fluctuations. Mark “-” represents negative correlation and “+” represents positive correlation.

Based on the annual status map and statistics, the coastal and shoreline, in particular, was severely affected by the process of coal mining. To analyze the above fluctuations, the authors have proposed the survey of points in the coastal area in 1997 and 2016 in Cam Pha area of Quang Ninh, Focus on where coal mining activities are taking place regularly here.

**Table 4. Statistics of survey points for coastal zone change from 1997 to 2016**

| No. | Distance [m] | Intensity [m/year] | No. | Distance [m] | Intensity [m/year] | No. | Distance [m] | Intensity [m/year] |
|-----|-------------|-------------------|-----|-------------|-------------------|-----|-------------|-------------------|
| 1   | 452.03      | 23.79             | 44  | 112.46      | 5.92              | 87  | 723.17      | 38.06             |
| 2   | 223.22      | 11.75             | 45  | 100.94      | 5.31              | 88  | 595.14      | 31.32             |
| 3   | 361.34      | 19.02             | 46  | 20.14       | 1.06              | 89  | 639.44      | 33.65             |
| 4   | 456.11      | 24.01             | 47  | 121.16      | 6.38              | 90  | 1029.12     | 54.16             |
| ... | ...         | ...               | ... | ...         | ...               | ... | ...         | ...               |
| 40  | 195.95      | 10.31             | 83  | 898.17      | 47.27             | 126 | -62.61      | -3.30             |
| 41  | 352.83      | 18.57             | 84  | 903.15      | 47.53             | 127 | 16.91       | 0.89              |
| 42  | 354.44      | 18.65             | 85  | 650.46      | 34.23             | 128 | -42.62      | -2.24             |
| 43  | 386.16      | 20.32             | 86  | 529.21      | 27.85             | 129 | 60.69       | 3.19              |

The use of remote sensing to determine the law of space expansion and urban development patterns is the most common tool today [11-14]. According to the Vinacomin report, the correlation between urban space expansion and coal production in Quang Ninh is a positive correlation, spatial correlation and distance gap expansion of urban area and coal mining area. Whereas without relying on satellite imagery after classification and matrix data volatility we can only confirm the correlation between urban space expansion and coal mining production based on qualitative, productive Coal mining increased and the urban land area in the area expanded in practice.

To calculate the correlation between coal production and urban space expansion in Cam Pha - Quang Ninh and find out the leading causes affecting the fluctuations of the coastal zone, the authors have collected statistics on land area, population and coal production of some coal mines in Cam Pha area at different stages.

**Table 5. Coal production of some mines and fluctuations of forests, lakes, and rivers during the coal mining process in Cam Pha - Quang Ninh from 1997 to 2016**

| No  | Mine  | 1997   | 2016   | Fluctuations area |
|-----|-------|--------|--------|-------------------|
|     | (1)   | (2)    | (3)    | (4)              | (5)   |
| 1   | Coc Sau | 1,950,960 | 20.25 | Forest - Coal |

In Table 3 we see the correlation of fluctuations. Mark “-“ represents negative correlation and “+” represents positive correlation.

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| 2   | 223.22      | 11.75             | 45  | 100.94      | 5.31              | 88  | 595.14      | 31.32             |
| 3   | 361.34      | 19.02             | 46  | 20.14       | 1.06              | 89  | 639.44      | 33.65             |
| 4   | 456.11      | 24.01             | 47  | 121.16      | 6.38              | 90  | 1029.12     | 54.16             |
| ... | ...         | ...               | ... | ...         | ...               | ... | ...         | ...               |
| 40  | 195.95      | 10.31             | 83  | 898.17      | 47.27             | 126 | -62.61      | -3.30             |
| 41  | 352.83      | 18.57             | 84  | 903.15      | 47.53             | 127 | 16.91       | 0.89              |
| 42  | 354.44      | 18.65             | 85  | 650.46      | 34.23             | 128 | -42.62      | -2.24             |
| 43  | 386.16      | 20.32             | 86  | 529.21      | 27.85             | 129 | 60.69       | 3.19              |
|   | Surface Mining | Cao Son | 3,833,889 | 19.17 | Forest - Coal |
|---|----------------|---------|-----------|-------|---------------|
| 2 | Surface Mining | 911,875 | 3,833,889 | 43.47 | Rivers and Lakes - Coal |
|   | Deo Nai        | 1,700,000 | 12.6     |       | Forest - Coal |
| 3 | Surface Mining | 1,030,810 | 1,700,000 | 13.59 | Rivers and Lakes - Coal |
|   | Khe Cham I     | 207,523  | 49,450   | 61.83 | Rivers and Lakes - Coal |
| 4 | Underground Mining | 303,870 | 1,056,361 |       |               |
|   | Mong Duong     | 1,508,995 | 57.87    |       | Forest - Coal |
| 5 | Surface Mining | 195,589  | 253,835  | 86.67 | Rivers and Lakes - Coal |
|   | Underground Mining | 234,775 | 1,255,160 | -     | -             |

The extraction, processing and consumption of coal is constantly increasing. According to the Vinacomin report (Vietnam National Coal and Mineral Industries Group), in 2016 and the first half of 2017, production volumes slowed down due to the impact of the economic downturn. However, in general, coal production is high. For example, in 2010, Vinacomin produced 33.12 million tons, which is 175% more compared to the production plan.

Summary
The results of research have shown that remote sensing technology and the use of its data are a significant advantage in tracking and assessing changes in territories, especially coastal areas in the Kampha region. It is shown that the considered typed objects (forest, rivers, lakes, etc.) are quickly and accurately determined using GIS technology and the relationships between the objects are quantitatively identified, which makes it possible to effectively conduct various case studies. The use of remote sensing data (images) in combination with GIS processing technology gives a holistic view of changes over large areas. In this regard, the presented methodology for the integrated assessment of the impact of coal mining on the coastal territory will allow for more efficient planning of their development, as well as solving environmental problems.

References
[1] Amorós-López J 2013 Multitemporal Fusion of Landsat/TM and ENVISAT/MERIS for Crop Monitoring (International Journal of Applied Earth Observation and Geoinformation) 23 132-141.
[2] Camps-Valls G 2011 Remote Sensing Image Processing (Synthesis Lectures on Image, Video, and Multimedia Processing) 5 (1) 1-192.
[3] Tseng K-H 2017 Reconstruction of Time-Varying Tidal Flat Topography Using Optical Remote Sensing Imageries (ISPRS Journal of Photogrammetry and Remote Sensing) 131 92-103.
[4] Verrelst J 2015 Optical Remote Sensing and the Retrieval of Terrestrial Vegetation Bio-Geophysical Properties–A Review (ISPRS Journal of Photogrammetry and Remote Sensing) 108 273-290.
[5] Tuia D 2014 Semisupervised manifold alignment of multimodal remote sensing images (IEEE Transactions on Geoscience and Remote Sensing) 52 (12) 7708-7720.
[6] Asadzadeh S and de Souza Filho C R 2016 A Review on Spectral Processing Methods for Geological Remote Sensing (International Journal of Applied Earth Observation and Geoinformation) 47 69-90.

[7] Tran V 2004 The Ha Long Bay World Heritage: Outstanding Geological Values (National Committee for ICCP, Vietnam).

[8] Broemme K, and Stolpe H 2007 Developing Environmental Concepts for Vietnamese Coal Mines (International Workshop Geoecology and Environmental Technology).

[9] Ky V N 1977 Hydrogeological Conditions of North Vietnam (Proc Acad of Mining and Geol, Hanoi).

[10] Nam T N 1995 The Geology of Vietnam: a Brief Summary and Problems (Geoscience reports of Shizuoka university) 22 1-9.

[11] Palaniyandi M 2012 The Role of Remote Sensing and GIS for Spatial Prediction of Vector-Borne Diseases Transmission (A systematic review, Journal of vector borne diseases) 49 (4) 197.

[12] Parchanski J 2016 Risk of Injuries Among Coal Mine Workers and Its Hysteresis (Mining University Notes) 222 869-876. DOI 10.18454/PMI.2016.6.869.

[13] Shabarov A N, Tsyrel S V, Goncharov E V, Zubkov V V 2016 The Technology of Extracting Gaseous Fuel Based on Comprehensive in Situ Gasification and Coalbed Degassing (Mining University Notes) 220 545-550. DOI 10.18454/PMI.2016.4.545.

[14] Zenkov I V 2018 Territorial and Technological Features of Opencast Mining in the Republic of Vietnam 12 102-103. DOI: 10.18796/0041-5790-2018-12-102-103.