Application of remote sensing to assess changes in shoreline and level of riverbed under the pressure of sand mining activities

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ABSTRACT

In 2010, about 11 billion tons of sand was used for construction in global; Vietnam is among the top ten sand producing countries. Sand mining has a significant impact on morphological characteristics, such as the degradation of the canal bed, erosion of the riverbank and the change in the shape of the river. In this paper, the monitoring of shoreline change on the riverbank is conducted in Krong No river belonging Dak Nong province. In details, remote sensing method is applied to determine main erosion locations and development of erosion distance by years by observing shoreline change in 2014–2018. The result shows that over the five years, the total erosion area on the right of riverbank (288.414 m^2) is twice as large as the left side (118.730 m^2). Moreover, 83.26 meters is the largest erosion distance. Duc Xuyen – Dak Nang communes are the most affected area by erosion. The article also discusses the simulation results of riverbed change. It shows that under pressure from the extraction of sand the riverbed is impacted, some points prone to erosion. Therefore, it raises a concern about sustainability with regard to the exploitation of sand and recommend that the local authority should define the maximum exploitable capacity to ensure that sand mining is conducted in a responsible manner for the future.

1. INTRODUCTION

In 2017, about 54% of the world's population is living in urban areas and it is assumed that by 2050 the percentage will reach 66% (UN, 2014). For these reasons, aggregate demand is very high, as concrete is commonly used in the construction industry. Considering concrete is the most widely used construction material in the world (BCNET Staff, 2016; Crow, 2008), and, for concrete production, each ton of cement requires approximately six to seven tons of sand and gravel (UNEP, 2014). The importance of this natural resource is given by the fact that, nowadays, after fresh water, sand is considered as the second most consumed natural resource on Earth (Villioth, 2014). United Nations Environment Programme (UNEP) stipulates that "Sand and gravel represent the highest volume of raw material used on earth after water "but also sounded the alarm over the fact that "their use greatly exceeds their natural renewal rates" (UNEP, 2014). (Lawal, 2011) considered that sand demand is growing rapidly, while, at the same time, its exploitation is becoming an environmental issue. The hydrodynamic behaviour of mining affected alluvial channel is still challenging due to the complex interaction between the flow and the mobile bed. Researchers have done on experiments with mining pit in flume, on empirical approaches for the migration of pit and channel bed deformation (Barman et al., 2017) and on turbulent characterization of flow in a mining pit region (Barman et al., 2018a). Presence of sand mining has significant effects on morphological characteristics such as channel bed degradation, erosion of riverbank and change in the plan form of a river. Ramkumar et al. (2015) investigated on sediment mining, dynamics of river bar and sediment texture characteristics of the Kaveri River, South India and documented the deterioration of natural fluvial system because of intensive sand mining activity and damming in the upstream river reach. (Brestolani et al., 2015) conducted investigation on change in morphology of the river caused by large scale mining of gravel in Orco River, situated in the Piemonte region by using CNR-IRPI experimental methodology based on multiyears LiDAR surveys realized in the years 2003, 2004, 2006, and 2007. The study by Brestolani et al. (2015) showed incision at pit upstream and downstream. Many of those erosion-distressed people loose not only their homes, means of livelihood and assets but also their previous identity, and they, therefore, often try hard for recognition of an identity (Das, 2010).

Remote sensing is an useful tool to monitor erosion due to ability of quickly capturing information and identifying variation of objects over time. (Casson, 2005) showed the high potential of multi-temporal remote sensing images for slip surface characterization of the la Clapiere landslide (French Southern Alps) by subtracting two DEMs of different years. It can really help to distribute well geophysical profiles or boreholes on unstable areas. Additionally, the article written by (Zende, 2012) focused on the study of the terrain and major land features of upper Krishna Basin (Yerala River) using remote sensing and Geographical Information System (GIS). The Landsat 7 TM and ETM+ images of the study area were processed and interpreted to extract information about land-resources delineation (forest-vegetation cover, water resources, and agricultural and residential areas) in the region. This method also used for detecting changes in shoreline and land around Rosetta Promontory, Egypt, these Landsat images adjusted by arithmetic and zoning, and then post-time multivariate analysis was performed to detect land cover changes, shore location changes (Masria, 2015). (Pham, 2013) published a journal to assess the erosion and deposition situation in Ca Mau and Bac Lieu coastal areas from 1995-2010 using remote sensing and GIS technology including Landsat and Alos. The shoreline is highlighted through the NDWI. Similarly, (Chu, 2014) used SPOT-5 images to build database by applying remote sensing and GIS to develop thematic maps to analyze the correlation between slope, elevation, flow, basin and vegetation factors and the risk of erosion in Ba Be National Park. In 2005, Tam Giang – Cau Hai lagoon applied Application of remote sensing to monitor erosion by using the color combination of near-infrared channels of satellite images collected at different times to clearly see the changes due to erosion and lagoon gate movement (Dien, 2005). Another article written by (Trinh, 2015) had researched about assessment of current situation of riverbank erosion in Dong Thap province by using integrated geographic analysis based on the status of riverbank erosion in the early 21st century to identify the causes as well as the rules, law changes.

Remarkably, Vietnam stood in leading sand and gravel producing and exporting countries in the world from 2010 to 2015. According to the report in 2017, over 10 households living along the river threatened, their property could collapse into the river at any time due to the Krong No River suffered by the erosion. The river section running across Krong No district in Dak Nong province has considered as a 'hot spot' of sand exploitation for many years. Although the local authority has licensed exploitation for the units, however, this phenomenon still happens in Krong No district. Therefore, it is extremely necessary to have a tool that can help local authority in identifying location and change over time of shoreline.

The main objectives of this paper are: (1) determine erosion areas from 2014 to 2018 (2) obtain erosion distance on two sides of the river from 2014 to 2018 (3) assessing the evolution of erosion areas under the pressure of sand mining locations.

2. STUDY AREA

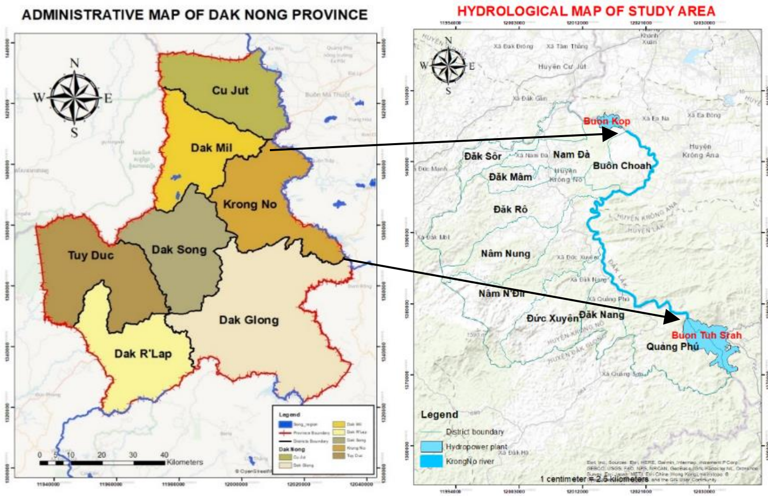

Figure 1 Study area

The scope of study is in Krong No river which flows along 5 districts in the province: Buon Choah, Nam N'Dir, Duc Xuyen, Dak Nang and Quang Phu districts (Figure 1). The total river basin area is 3920 km² and the main river length is 156 km located between Serepok Hydroelectric Reservoir and Buon Kuop Hydroelectric Reservoir. Moreover, there are 10 licensed sand mining locations located along study area (Figure 2).

No.	Districts	Name	X	Y
1	Buon Choah	BC1	824614.88 m E	1378573.67 m N
2	Buon Choah	BC2	821689.72 m E	1376922.28 m N
3	Nam N'Dir	NN	816659.65 m E	1372728.27 m N
4	Duc Xuyen - Dak Nang	DN	820268.58 m E	1364962.25 m N
5	Quang Phu	QP5	822312.76 m E	1363108.39 m N
6		QP6	823212.29 m E	1362620.10 m N
7		QP1	823455.03 m E	1361228.56 m N
8		QP2	826557.07 m E	1361345.78 m N
9		QP3	827657.12 m E	1361445.81 m N
10		QP4	828457.08 m E	1360585.80 m N

Figure 2 Sand mining location in study scope

3. MATERIALS AND METHOD

The remote sensing images used in this research is Landsat 8 OLI. The Operational Land Imager (OLI) which collects data in the visible, near infrared, and shortwave infrared wavelength regions as well as a panchromatic band.

3.1. Input data

The research uses the input data from five satellite images Landsat 8 from 2014 to 2018 (Table 1) which is downloaded from website http://earthexplorer.usgs.gov.

Table 1 Satellite images

No	Name	Date
1	LC08_L1TP_124052_20140303_20170425_01_T1.tar.gz	2014-03-03
2	LC08_L1TP_124051_20151117_20170402_01_T1.tar.gz	2015-11-17
3	LC08_L1TP_124051_20160308_20170328_01_T1.tar.gz	2016-03-08
4	LC08_L1TP_124051_20170207_20170216_01_T1.tar.gz	2017-02-07
5	LC08_L1TP_124051_20180210_20180222_01_T1.tar.gz	2018-02-10

3.2. Software

The research supported by two softwares: Envi5.2 and ArcGIS, and support with DSAS tool (Digital Shoreline Analysis System).

3.3. Method

Application of remote sensing data can quickly capture information and identify variation of objects over time due to regular updating capabilities. The aim of using remote sensing in order to characterize the geometry of erosion slip surface and its spatial and temporal evolution by subtracting shorelines of continuous years. Furthermore, adding sand mining locations to investigate the change.

Diagram of remote sensing method is presented (Figure 3). The details of three main steps of analysing satellite images are also illustrated.

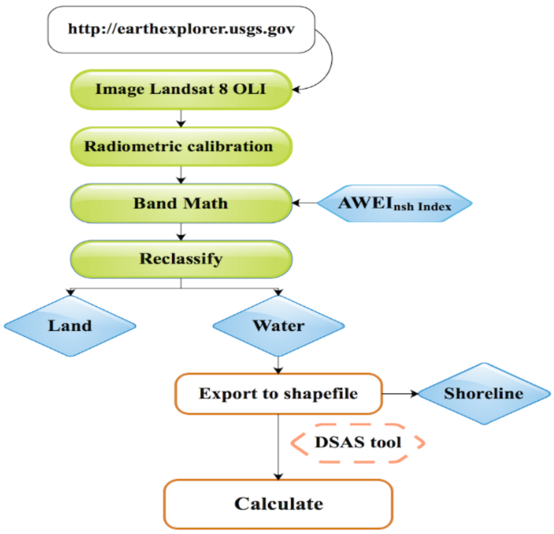

Figure 3 Diagram of remote sensing method

Step 1: Calculating Reflectance value from the Satellite data

OLI spectral radiance data can also be converted to TOA planetary reflectance using reflectance rescaling coefficients provided in the landsat8 OLI metadata file. The equation (1) is used to convert DN values to TOA reflectance for OLI image. The value of each parameters from satellite images is provided in Table 2

$$\rho\lambda = (M\rho*Qcal + A\rho)/(\sin \theta_{SE}*(!pi/180)) \quad (1)$$

Where

Mρ: Band-specific multiplicative rescaling factor from the metadata

Aρ: Band-specific additive rescaling factor from the metadata

Q cal: Quatized and calibrated standard product pixel values (DN).

θ_{SE}: Local sun elevation angle. The center elevation angle in the degrees is provided in the metadata (Sun elevation).

Table 2 Parameters from satellite data

Year	M_ρ	A_ρ	θ_{SE}
2014	2.0000E-05	-0.100000	56.53159191
2015	2.0000E-05	-0.100000	51.88482425
2016	2.0000E-05	-0.100000	57.22411947
2017	2.0000E-05	-0.100000	50.03994972
2018	2.0000E-05	-0.100000	50.60325931

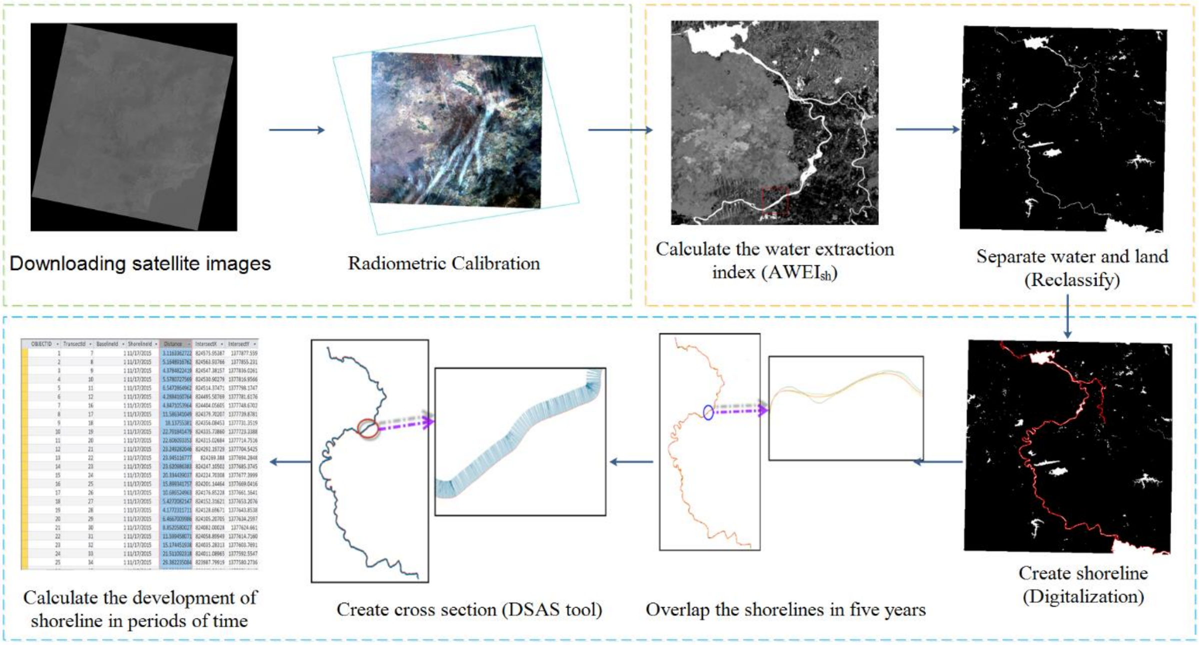

Figure 4 Procedure of analysing shoreline change (Envim EmsLab, 2019)

Step 2: AWEI (Formulation of the Automated Water Extraction Index)

The five Landsat 8 spectral bands were used in the development of the new index (AWEI) to increase the contrast between water and other dark surfaces. The main purpose of building AWEI is to maximize the ability to separate water and non-water pixels through differentiation of the frequency range, to supplement and apply different coefficients (Jugie et al., 2018).

$$\boldsymbol{AWEI_{nsh} = 4 \times (\rho_{band2} - \rho_{band5}) - (0.25 \times \rho_{band4} + 2.75 \times \rho_{band7})} \quad (2)$$

$$\boldsymbol{AWEI_{sh} = \rho_{band1} + 2.5 \times \rho_{band2} - 1.5 \times (\rho_{band4} + \rho_{band5}) - 0.25 \times \rho_{band7}} \quad (3)$$

Where ρ is the calibration value of the Landsat 8 OLI bands: band 3 (Green), band 6 (SWIR 1), band 5 (NIR) and band 7 (SWIR 2).

Step 3: Calculating Shoreline Change

In this step, the Digital Shoreline Analysis System (DSAS) version 4.3 is an add-in applied to Esri ArcGIS desktop v.10.1 that enables to calculate shoreline rate-of-change statistics from multiple historical shoreline positions. It provides measurement locations, performs rate calculations, the statistical data about shoreline change in study area.

After creating shoreline, in order to have the erosion area on each sides of the river, merge tool is utilized to find the answer. Then using DSAS tool to calculate the highest distance, and determining main locations in each commune (Figure 4).

4. RESULTS AND DISCUSSION

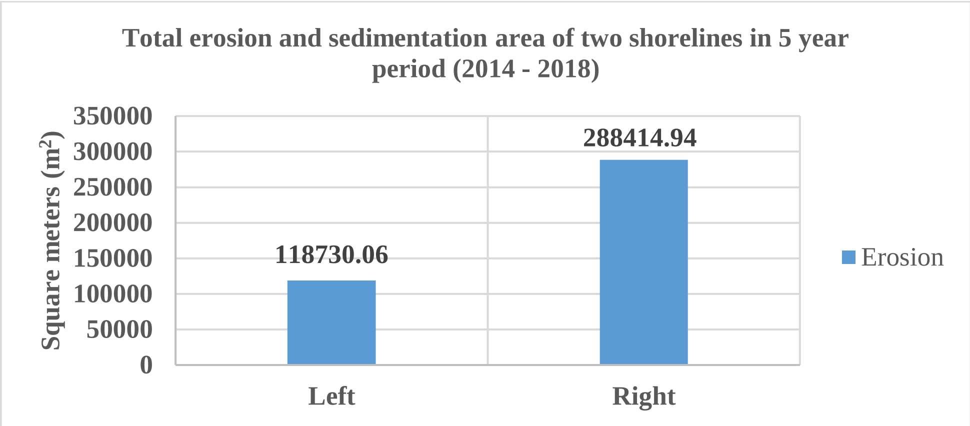

Figure 5 Total area of erosion on right and left shorelines (2014 – 2018)

The results divided into left and right shorelines. The figure reveals that erosion phenomenon concentrates on the right shoreline. It is nearly double than the left one.

4.1. Left shoreline

There are four survey erosion locations located along upstream, middle stream to the downstream of the river, which represents for four communes that sand mining allowed (Figure 6). In term of areas, Duc Xuyen – Dak Nang communes have the largest number through 5 years. Following that is Nam N'Dir, Buon Choah and Quang Phu with 41051.96 m^2, 9118.019 m^2 and 7477.496 m^2 respectively (Figure 7). Besides, the largest distance is in Duc Xuyen – Dak Nang commune (83.26 meters). Moreover, it tended to increase in the next year 2018, except for Buon Choah commune the figure dramatic decreased (Figure 8).

4.2. Right shoreline

Similarly, erosion situation on right shoreline is also described in 5 years period from 2014 to 2018. By overlapping shoreline of the river in each year, the change between years defined. The research locations on the right shoreline are located at two districts Nam N'Dir and Duc Xuyen-Dak Nang (Figure 9). Duc Xuyen – Dak Nang region had total erosion area with 145,946 m^2 accounting over 50% of the erosion area on the right shoreline (Figure 10). In details, the highest distance belongs to the Nam N'Dir with approximately 75 meters while that of at Duc Xuyen – Dak Nang is nearly 64 meters. Especially, both locations experienced the highest erosion distance in 2017 and slight reduced in the next year, 2018 (Figure 11).

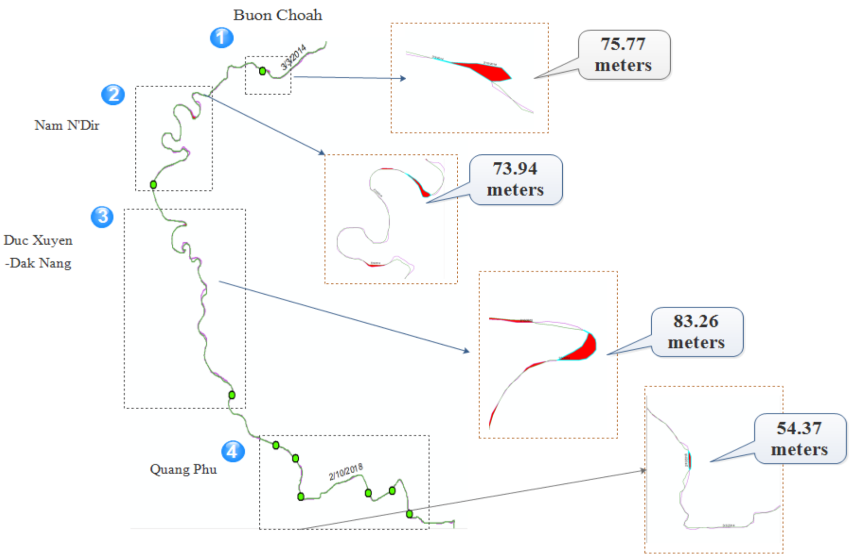

Figure 6 Four survey locations on the left shoreline

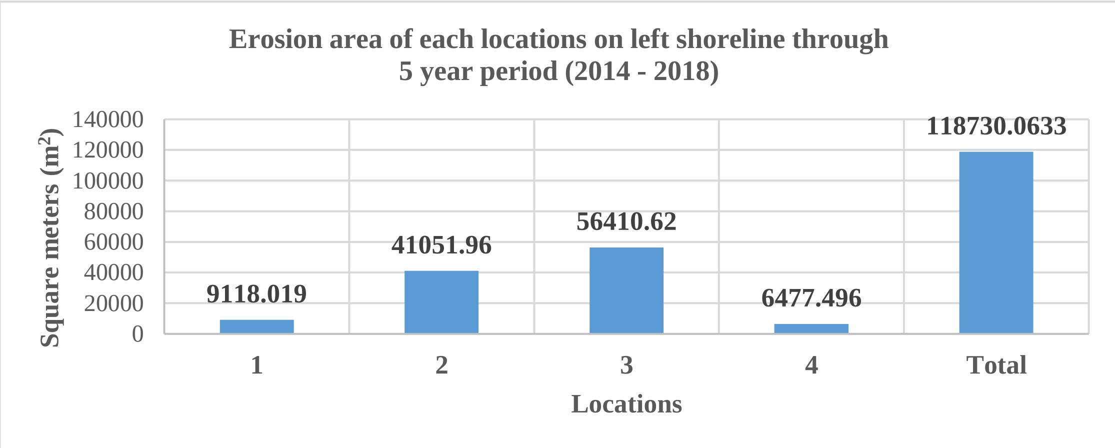

Figure 7 Erosion area of each locations on left shoreline

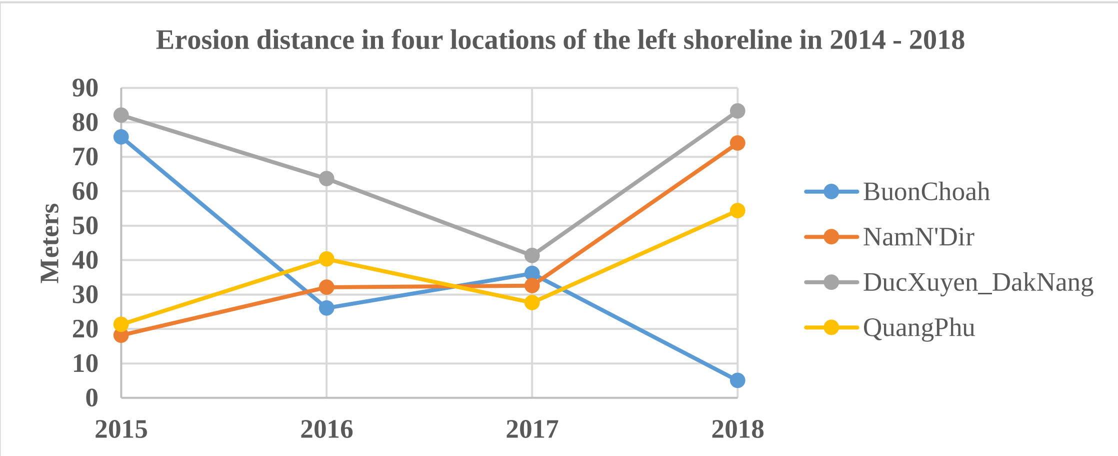

Figure 8 Erosion distance in four survey locations of the left shoreline

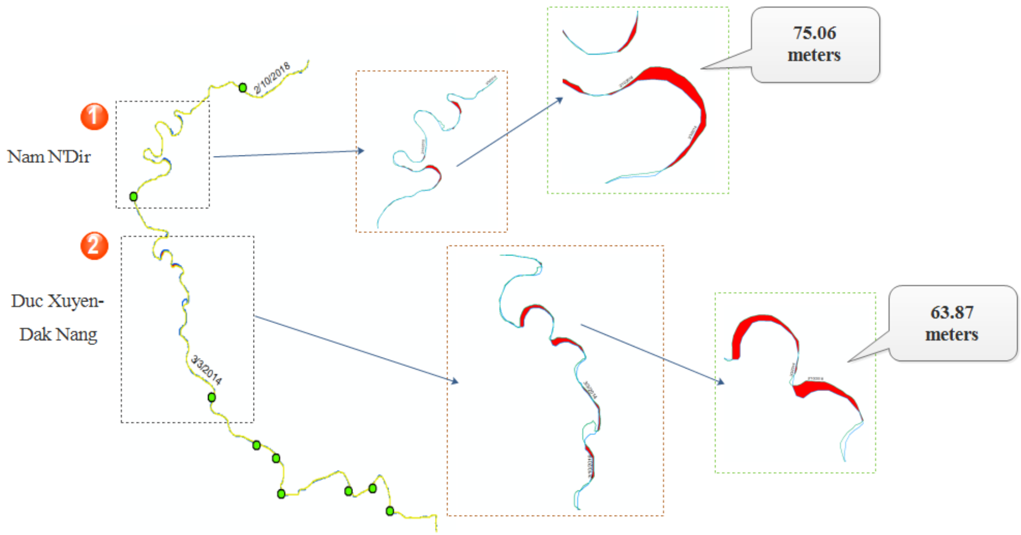

Figure 9 Two survey locations on the right shoreline

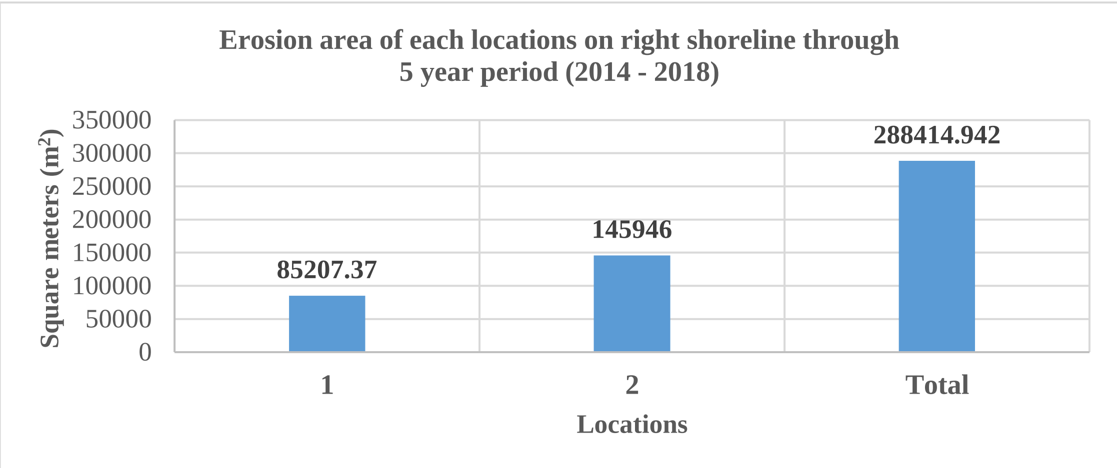

Figure 10 Erosion area of each locations on left shoreline

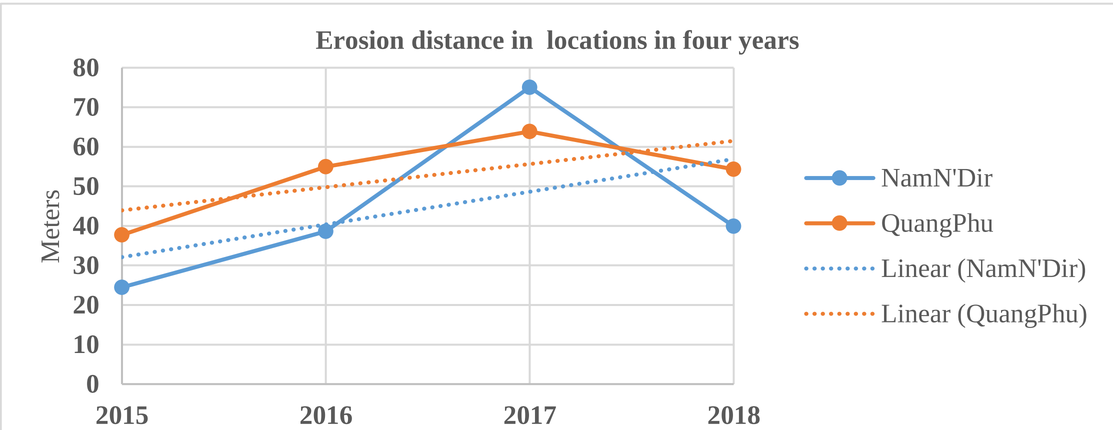

Figure 11 Erosion distance in two survey locations of the right shoreline

4.3. Simulating erosion evolution

The method is using the developed numerical models to investigate the flow direction and surface elevation of river through hydrodynamic model. After validating by using NASH index sand transport model was applied to identify the evolution of erosion through the change of riverbed level (Figure 12).

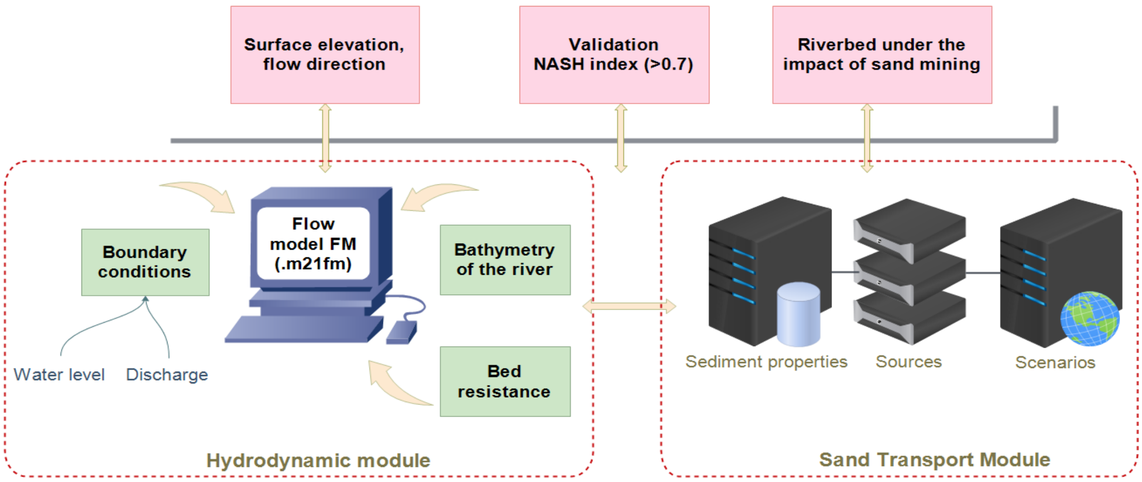

Figure 12 Modelling MIKE 21 method

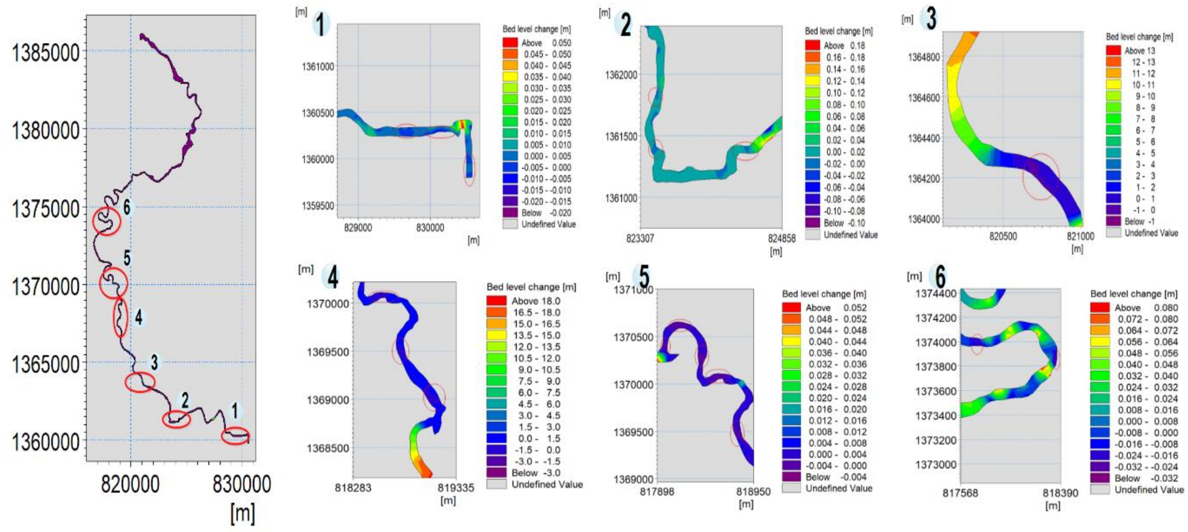

Figure 13 Six survey locations eroded under the operation of sand mining activities

By using Sand transport module of MIKE 21, there are six erosion locations investigated. Red circles represents for which points prone to erode under the operation of sand mining. Most of them concentrate on the meanders of the river, exclude for Buon Choah commune where was not effected by this activity. Especially, it shows that the risk of erosion in Duc Xuyen – Dak Nang communes are larger than other locations.

5. CONCLUSION

The results of satellite images giving the situation of erosion phenomenon in study area. Erosion area and distance in Krong No river tends to increase by years. In 2018, it was dramatic increased leading to the existence of the highest distance, 83.26 meters. Duc Xuyen and Dak Nang communes are the most effected places with over 56,000 m^2 on the left and 145,946 m^2 on the right, accounted for nearly 50% of total erosion area on each side. Especially, a large amount of erosion area located on the right shoreline (288.414 m^2) than the left one (118.730 m^2) that belongs in Dak Lak province. Moreover, combination of modelling gives the picture about the risk of erosion in the study scope through the riverbed. In conclusion, the erosion phenomenon tends to erode on the right of the river, and erosion area is broaden by time. The application of remote sensing and modelling can help monitor the shoreline change of the river annually to have appropriate solutions to minimize this disaster.

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