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Research Article

Using landsat satellite images for assessing riverbank changes in the Mekong and Bassac rivers in the An Giang province

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ABSTRACT
An Giang Province is one of the key economic regions of Mekong Delta and of Vietnam. With the development of urbanization and industrialization, An Giang has been suffering a burden from natural disasters, including salinity intrusion, drought, and riverbank erosion, due to natural and anthropological drivers. Amongst them, riverbank erosion is a key problem of the An Giang province, caused by changes in hydrological and sediment characteristics because of hydropower development and sand exploitation in the upstream part. In this study, we investigated the riverbank changes by using the water extraction index based on the Landsat imagery data. Amongst three extraction indices, such as Normalized Difference Water Index (NDWI), Modified Normalized Water Index (MNDWI), and Automated Water Extraction Index (AWEI), AWEI was identified the suitable index for the study area replied on the assessment of the index performance in extracting the riverbank in the four test sites in An Giang province (An Phu District, Vinh Hoa District, Cho Moi District, and Vam Nao River). Based on that, AWEI was then used for riverbank extraction for the study area in the period 1989-2015. After using the AWEI riverbank extracting method, Linear Regression Rate (LRR) had been applied to estimate the rate of the riverbank changes in the study area. The results stated that the rate of riverbank erosion was high in meandering river segments and upper part of islets, such as Tan Chau (-33m/year), Cho Moi (-36m/year) and Vam Nao (-3.07m/year). Besides analyzing the rate of erosion, this research also discusses some potential reasons as well as protection method to mitigate this problem. This study reveals that it is crucial to take sustainable measures to mitigate erosion in An Giang province.
Key words: MNDWI, AWEI, NDWI, remote sensing, DSAS, riverbank change, An Giang province

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INTRODUCTION

The riverbank change is normally controlled by the natural process through several decades including climate change, deposition process in floodplains and riverbank[1]. However, human interventions play an important role in the riverbank variation, consisting of sand mining, hydropower development, and construction of reservoirs and bank protection works, which changed the hydrodynamic regime of rivers[2–4]. In recent years, dam construction activities are one of the main causes of the reduction of supplied sediment, leading to more severe erosion[5,6]. In addition, channel instability as result of riverbank protection works has put considerable pressure on the riverbank[1]. These human interventions can have a strong impact on the environment and socio-economy, accelerating the imbalance of the riverbank sediment budget and loss of riverbanks, imbalance of the bottom structure and substitution changing ecosystems and fisheries.

An Giang is located upstream province where waterways rivers connecting Mekong Delta which is one of the essential economy provinces in Mekong Delta. With benefit coming from geographical and natural conditions along Mekong and Bassac Rivers, An Giang has been becoming potential economic development about agriculture, fishing, border economic, industrial processing, production of construction materials and tourism services. Morphological changes in combination with characteristics of geography, environment, and development planning have caused the rate of erosion developed strongly, especially in recent years tended to raise threatening people, destroyed infrastructure in the body, causing damage to property wealth. Therefore, more attention should be pay to management and monitoring riverbank erosion from governments and scientists.

Riverbank erosion is gradually becoming an urgent problem and adversely impact on local socio-economic. The illegal exploitation of sand has complicated developments with the construction of spontaneous constructions on the Mekong and Bassac Rivers caused riverbank erosion and threatened the lives of the people. The riverbank erosion trends become more complicated and more frequent, especially in

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the Mekong, Bassac, Vam Nao, Binh Di, and Chau Doc Rivers and large canals such as Tan An Xang, Cai San with a total of 50 landslide cases in 2016. According to the field measurement report in 2009, An Giang province has 40-43 areas potential erosion with the slip coefficient about 0.44-0.96, which belongs to the range of slightly dangerous levels. The phenomenon of erosion occurs in short sections interleaved from 5m to 40m with the sliding rate ranging from 1m-20m/year, especially in Vinh Hoa, Tan An - Tan Chau Town, Tuan My - Cho Moi District. The erosion trend of these places moves into the lower river[7]. The erosion of An Giang in the period of 2005-2009 brings damages: 41.44 thousands of billions VND dong, the area is 15553 m2, the house relocated is 2090. The consequences impact on 172 houses and caused 20 houses to collapse in the Bassac River, with damage estimated at more than VND 89 billion (US$3.9 million). According to the provincial Department of Agriculture and Rural Development (DARD) concluded that at least 19 erosion spots, covering a total length of 1,738 meters along the riverbank in An Giang province have been detected since 2017.

There are several methods to monitor riverbank changes in Mekong and Bassac River including hydrodynamic modeling, in-situ, and remote sensing method. Among them, remote sensing is still a suitable and effective tool for monitoring and identifying riverbank change. Remote sensing provides free-resources (such as Landsat images) and allows repeatable reviews throughout the historical and spatial variations of river systems. There have been evidently numerous studies on utilization of remote sensing technology for riverbank change assessment such as land use change detection in Mekong Delta using time series[8–11]. Both[12–14] proposed that new approaches to extract land use and riverbank in Mekong Delta for monitoring historical riverbank changes by time series remotely sensed data and multi-spectral images. However, there are still limited studies conducted for comprising the performance of water indices for riverbank extraction in Vietnam. Moreover, many studies carried out to assess riverbank and coastal changes in the Mekong Delta River, but no far studies concentrated separately on riverbank and islets morphological changes in An Giang.

The results of the study provided a comprehensive understanding of riverbank erosion and accretion in the Bassac and Mekong Rivers in An Giang province with change rates of riverbank and mechanisms/ causes. Using geographic information system (GIS) and remote sensing- processing images techniques, this study aimed to extract water bodies by the spectral water indices Normalized Difference Water Index (NDWI)[15], the Modified Normalized Difference Water Index (MNDWI)[16] and the Automated Water Extraction Index (AWEI)[17]. Subsequently, Linear Regression Rate (LRR) methods are used to determine the riverbank and islets changes. In general, this study demonstrated the prominent role of river meandering in erosion in An Giang province, but the erosion rates of river banks varied largely in time and space because this process is a composition of hydrological and sedimentation alterations due to upstream damming, sand mining, and a tropical cyclone. Hence, the results of this study would meaningfully verify and explain corresponding mechanisms/causes in other related study areas.

STUDY AREA

An Giang province is one of four key economic areas (An Giang, Kien Giang, Can Tho and Ca Mai) of Mekong Delta, with an interlaced river system (Figure 1). An Giang not only provide abundant aquatic resources for Mekong Delta but also is a highly productive agricultural region that have more than 1000 rice mills, of which more than 200 have larger capacities above 100 t/d[18]. However, with the increasing significant affected from causes on riverbank erosion: (1) reduced sediment influx because of the construction of dams upstream of the Mekong River and hydropower dam issue; (2) erosion due to over-controlling sand-mining; (3) significantly decrease in flow distribution in Vam Nao Rivers. These cause impacts on provincial sustainability.

METHODOLOGY

Remote sensing data

To implement riverbank change assessment in An Giang province, this research used on the normal length of the national length of 30 m Landsat includes: eleven scenes of Landsat 4-5 (TM), two scenes of Landsat 8 Imager Land Operate (OLI / TIRS), which data images (path 125 row 052, path 125 row 053, path 126 row 052 and path 126 row 053) obtained from the US Geological Survey (USGS) Global Visualization Viewer. All the images were obtained for the different seasons. The obtained Landsat data (Level 1 Terrain Corrected (L1T) product) were pre-georeferenced to UTM zone 48 North projection using WGS-84 datum. The other necessary corrections were performed in this study. The images of images months from month 12 to month 6, this is the image to the summer fall, screen covers than 10% overlay on all areas or no touch sensor.

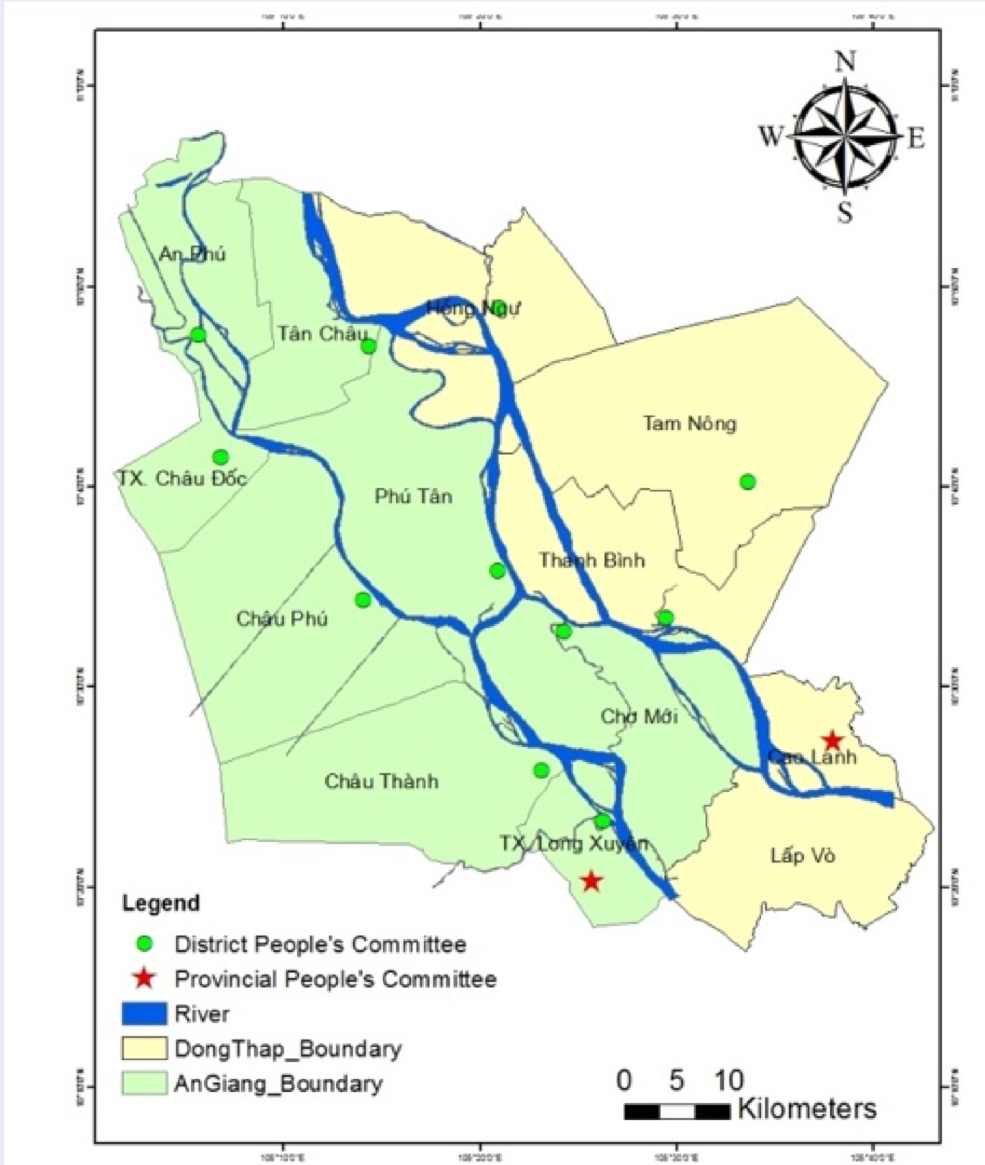

Figure 1: Location maps of the An Giang province in Mekong Delta

Riverbank Extraction method

Various water indices have been developed to assess riverbank changes, including Normalized Difference Water Index (NDWI) [15], Modified Normalized Difference Water Index (MNDWI) (Xu, 2006), and Automated Water Extraction Index (AWEI) [16]. In this study, AWEIsh was chosen to extract water bodies from the shadow and build-surfaces, because this index was applied successfully in the numerous of studies on water extraction in the similar environmental conditions [19,20].

Automated Water Extraction Index (AWEI) used to extract water bodies from showdown and low albedo surfaces [17]. Particular, no existing the water index was able to automatically separate water and shadowed surfaces. AWEIsh is primarily formulated for further improvement of accuracy by removing shadow pixels. The subscript "sh" in Eq. (1) indicates that the equation intended to effectively eliminate shadow pixels and improve water extraction accuracy in areas with shadow and/or other dark surfaces. But in areas with highly reflective surfaces such as ice, snow and reflective roofs in urban areas, may misclassify such surfaces as water. The formulas of AWEIsh are expressed as follows:

AWEIsh= Blue +2.5*Green -1.5*(NIR+SWIR1) - 0.25*SWIR2 (1)

where ρ is the reflectance value of spectral bands of Landsat 5 TM: band 1 (blue), band 2 (green), band 4 (NIR), band 5 (SWIR) and band 7 (SWIR).

After extracting the riverbank from the Landsat data, the DSAS method was used to calculate the shear rate and shore change[21]. Construction of baselines constructed 150 m above the mainland. Following the two set transect parameters, transect spacing contains 25m for all the riverbanks; however, transect length depends on the distance of all riverbank, but it meets the requirement of crossing all the riverbank. Intersection of cross-sections and riverbanks will provide DSAS a basis for calculating statistics that change over time.

Based on the purpose of this thesis, LRR tools selected to determine riverbank changes. Due to the morphological and environmental condition, LRR values classified into seven levels as follows: high erosion (<5 m/year); medium erosion (-5 to -1 m/year); low erosion (-1 to -0.5 m/year); stable bank (-0.5 to 0.5 m/year), low accretion (0.5 to 1 m/year); medium accretion (1 to 5 m/year); high accretion (>5 m/year) (Roy et al., 2018).

RESULTS AND DISCUSSION

Analysis of riverbank changes from 1989 to 2015.

The riverbank has extracted from Landsat satellite in the different years (1989, 1994, 2001, 2005, and 2015) by image-processing techniques. The riverbank change maps during the period 1989-2015 presented in (Figure 4). The average erosion rate was -1.335 m/year and -0.395 m/year for the Mekong and Bassac River, respectively. Additionally, the rate was -3.07 m/year for Vam Nao River.

The LRR (m/year) from 1989 to 2015 values calculated to determine the changes in the length of the riverbank, and planform characteristics of the two main river branches and Vam Nao River. LRR values were analyzed to assess riverbank changes in the study area. On the right bank, the mean value of Mekong was -4.45 (m/year) that reveals this branch experienced the moderately erosion process during 16 years, which might be related to the movement of the sandbar transportation in upstream. As can be observed, erosion occurred on the left bank side of Bassac River, especially nearby -2.43 (m/year). Significantly, there were various regions being the rate of erosion up to nearly -36 (m/year) belongs to Cho Moi in the Bassac area (Figure 4). The increased accretion of islet at Chau Phu district causes the flow to shrink and contemporaneously meandered river, leading strong water flow. This is the reason why the vortex hole moves to the shore. Additionally, heavy construction on soft-ground soil is also a factor increasing the collapse of riverbanks. The Vam Nao River is the connected river segment between Mekong and Bassac Rivers, resulting from the flow bifurcation between the Mekong River and the Vam Nao River. The morphological changes of Vam Nao River make Mekong River changes more complicated, which was eroded about -3.07 (m/year). Considerable bank accretion occurred on the left side of the Mekong River and the right side of Bassac River, with 1.78 (m/year) and 1.64 (m/year), respectively.

The cause of bank erosion is discussed in terms of planform development. Because of the meandering course, meandering tract SI (Sinuosity Index) > 1.1 values can only be found from the Vam Nao river connection (to upstream) on the Bassac River (Figure 2) while the Mekong has SI > 1.1 values for all river segments[22]. Another cause of bank erosion comes from fault, resulting in a horizontal movement and then bends of Tan Chau area gets 90 degree (Figure 3). Another main erosion in Tan Chau causes the flow directly impact the riverbank, destabilizing land mass. Due to the narrow-flowed and the meandering at Tan Chau - Hong Ngu, the vortex is more than 45 m deep formed here. This vortex moves into Tan Chau riverbank is considered the main cause of riverbank erosion. Moreover, the vortex area under the riverbed tends to develop in-depth and increasingly squeezes closer to the foot of the embankment, leading the risk of instability of the foot of the embankment[23,24]. Consequently, the high erosion rate of Tan Chau was -33 m/year.

In addition to the meandering and morphological characteristics of the river in the river-dominated area, sediment supplies considerably affect erosion and accretion processes. The development of economies in the Lower Mekong Basin (LMB) considered the fast rates of economic growth of the last decades between 1993 and 2003. Economic growth and electricity demand considerably increased at an average annual rate of about 8%[25]. Although there are having several advantages of rapid drivers of development, notably planned large-capacity dams, mainstream projects would have a significant negative impact on the fisheries and agriculture in Lower Mekong Basin, including Vietnam. The number of hydropower mainstream in China build about six

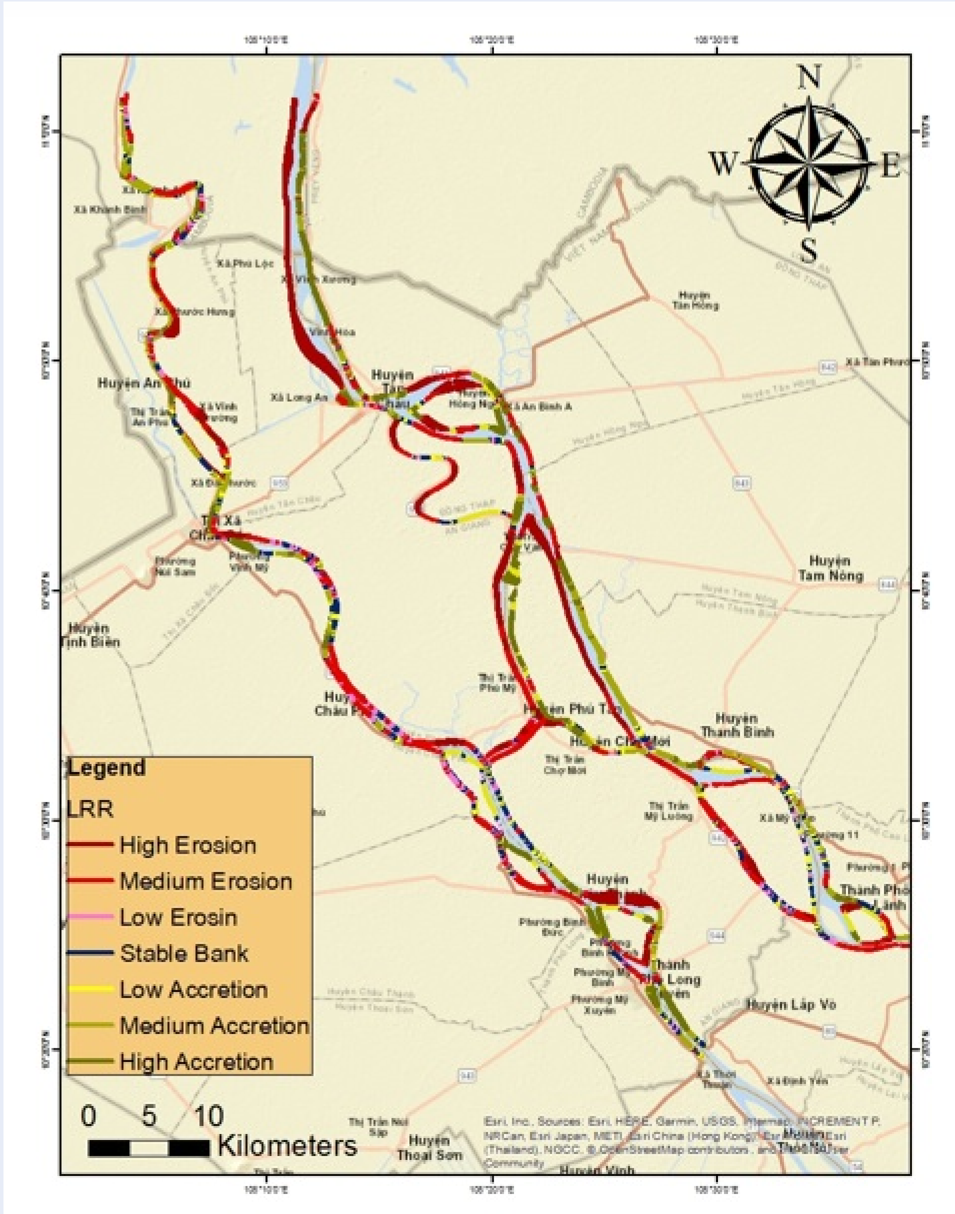

Figure 4: Riverbank changes in An Giang Province from 1989 to 2015

over eight dams, including two dams large capacity of about 22.2 billion m¬3/year. Simultaneously, the dams on tributary were 142 with a capacity of about 76.6 billion, participating in four countries: Laos, Cambodia, Thailand, and Vietnam. The hydropower activity prevented the dynamic equilibrium of the Mekong River, leading to large areas of the alluvial channel. The loss of fishery is estimated at USD 476 million per year, respective with 10%. Because they are increasingly constructed of hydropower, 45% percent of river gardens will be a vulnerability, including agricultural land and transmission line. According to the Strategies Environment Assessment Report of Mekong River Commission –MRC SEA (2010), this project is the main reason for the decrease of suspended sediment loads into downstream from 73 to 42 million tons/year[26]. The growing vulnerability of ecosystem and irreversible environmental damage are consequences of the mainstream project, losses in long-term health and productivity of natural systems, and losses in biological diversity and ecological integrity. LMB mainstream projects would have

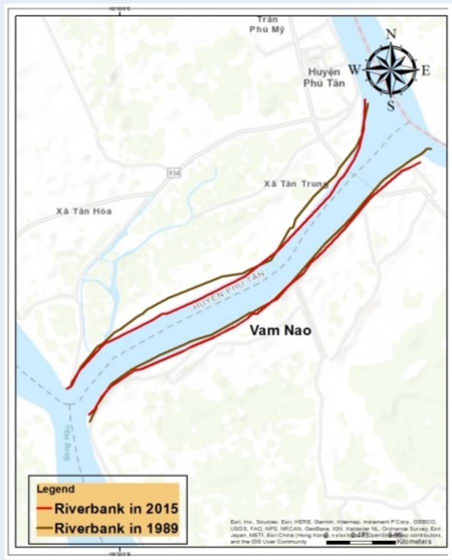

Figure 2: Riverbank erosion caused from flow bifurcation on Vam Nao River

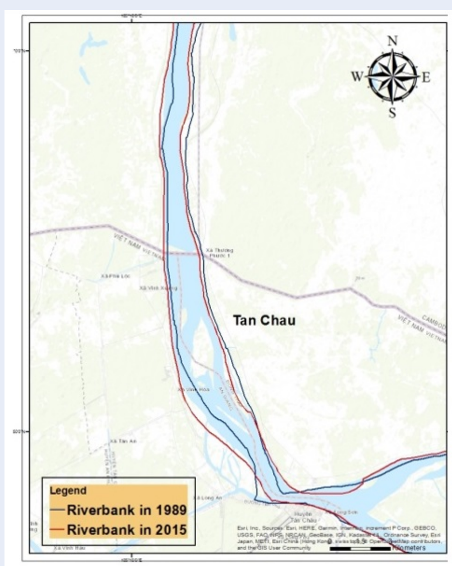

Figure 3: Riverbank erosion in a meandering course (SI > 1.1)

significant additional basin-wide effects on the future movement of water and sediment through the Mekong basin system, including balance subsidence (Figure 5)[27].

The secondary factor coming to over sand-mining problems, there is cannot be denied that sand-mining activity at Vam Nao River and nearby An Giang riverbank area has been complained and concerned by local people. With the increasing demand for land leveling in construction, numerous of illegal company excavate sand in some sensitive areas, resulting in erosion problems. As for the result in this activity is one of the main reasons for riverbank change and sediment flow.

The third component is flow distribution between Mekong mainstream (Tien) River and Bassac in Vam Nao River. The increasing volume of Bassac transferred into Vam Nao River which increases potential erosion in the study area due to 'bedload' component

Bank protection works

Regarding the bank protection works along the Mekong and the Bassac River, a variety of observation and suggestions provides to cope with bank erosion and reduce damage, including technical (floodplain/riverbank zoning, institutional and legal aspects, and controlling human activities) and non-technical (vegetation control, groins, dikes and revetment) measures. However, based on the morphological characteristics and erosion mechanisms in this study area, there are some suitable measures suggested to apply. The severity of erosion at Tan Chau is a specific example of meander-bend morphology. In this area, we propose two integrated measures to mitigate erosion damages. Firstly, the floating screen measure can be appropriate solutions to prevent flow directly impact into the riverbank (Figure 6). Furthermore, longitudinal protection structures are installed on river banks parallel to the river course, generally with the aim of protecting adjoining areas from inundation, erosion, and river meandering. They are usually constructed on natural banks and extend for a considerable distance. The most common structures are embankments or levees in the form of guide bunds or banks, afflux bunds, and approach embankments.

The erosion in Ong Ho islet can be eliminated by building long embankments in front of the right bank of Ong Ho islet and dredging plan on the left bank of the islet. The erosion area has a high riverbank slope, water transportation frequently; therefore, the riverbank protection works is the priority requirement. The proposed soft-technical solution is to use gabions,

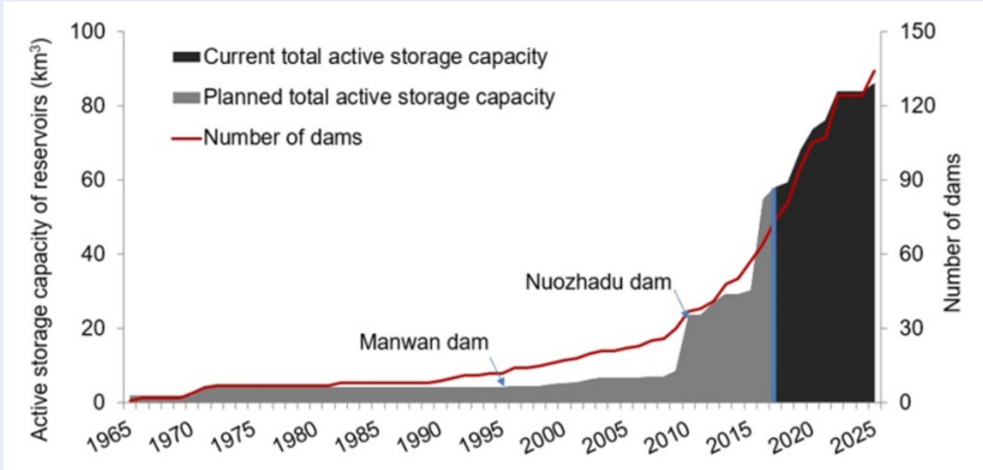

Figure 5: Number of dams and corresponding total active storage capacity over the time in the Mekong River Basin [28]

Figure 6: Floating screen for meandering river [29]

which are located just outside and along with the islet. The building of these gabions prevents high flow velocities and impacts caused by water traffic. The combination of coir rolls directly above the gabions to increase the efficiency and resistance for this critical riverbank erosion area (Figure 7). In this system, wooden piles fix coir and coir rolls. Depending on the topographical area, it is possible to use the stones with appropriate sizes to pre-block the gabions, increasing the stability of the gabions. Additionally, it is recommended to use coir rolls that have already integrated vegetation to the system to achieve rapid results.

CONCLUSION

One of the main purposes of this study is to assess water extraction indices and select the best one to extract riverbank in An Giang province. The results showed that the overall accuracy and other assessment indicate of AWEIsh from water bodies extraction is dominated than the other three water indices in four test sites. Therefore, AWEI is proposed as an alternative and improved water index, especially in extracting water information from areas where noisy results are expected because of the presence of shadows and built-up surfaces.

Riverbank has extracted and assessed from 1989 to 2015 along the Mekong and Bassac River, provided information for assessing and managing bank erosion in An Giang province. In general, riverbank changes have been caused by natural. The study showed that meandering morphology plays an important role in erosion mechanisms of An Giang province in both main branches and islets. In addition, the flow distribution in Vam Nao River also has influenced the flow direction and sediment supply between upstream and downstream of the Mekong River. Erosion and accretion process seemed to be continuously, leading bedload fluctuation problems in Bassac River. Furthermore, the anthropological activities interventions in these natural areas as sand-mining, hydropower dam and waterway transportation have also accelerated erosion in Mekong and Bassac River.

As river bank erosion rates have accelerated and riverbank erosion is becoming more serious in recent years, stabilization and river bank protection works should be considered to reduce damages on the environment. Solutions overcome the current phenomenon of riverbank erosion often trends to long-term stability. Hard construction solutions just use in the case of emergency. Environmentally friendly

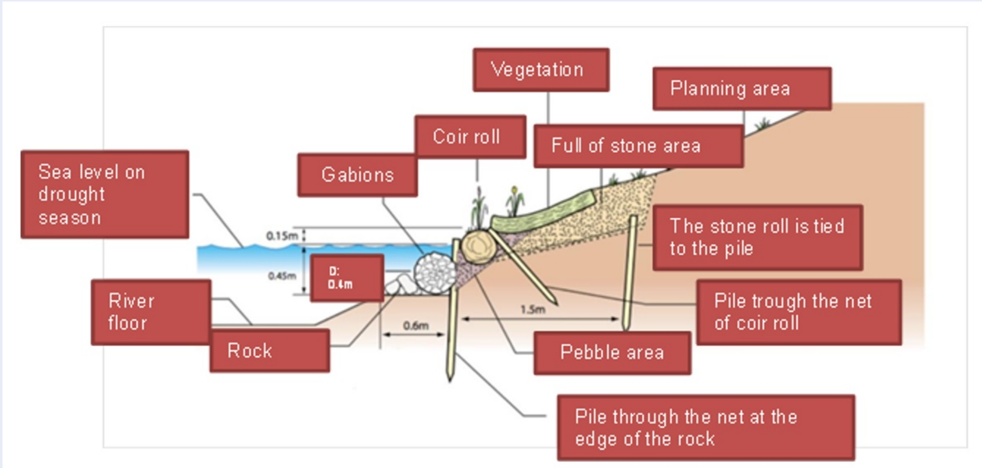

Figure 7: Coir and rock roll measures in Ong Ho islet [30]

and soft solutions are being the priority. Proposals for riverbank stabilization, anti-erosion measures are being designed with constructive trends to the flows gradually return their original natural flowing state without human interventions.

In this thesis, the extraction riverbank from satellite images verifies its advantages rather than other methods. Nevertheless, the limitation of moderate spatial-resolution imagery should consider in precise monitoring which made impossible users to see detailed information. In the future, the modified satellite products can develop the precision of results. On the other perspectives, using the dykes protection may be facing the problems of partially collapsed, causing a traffic hazard and the dike could not be realigned because of adjacent properties.

LIST OF ABBREVIATIONS

AWEI: Automated Water Extraction Index

AWEIsh: Automated Water Extraction Index (shallow)

DARD: Department of Agriculture and Rural Development

GIS: Geographic Information System

L1T: Level 1 Terrain Corrected

LMB: Lower Mekong Basin

LRR: Linear Regression Rate

MNDWI: Modified Normalized Water Index

NDWI: Normalized Difference Water Index

NIR: Near- Infrared

OLI: The Operational Land Imager

CONFLICT OF INTEREST

There is no conflict of interest.

AUTHOR'S CONTRIBUTION

The authors declare that all authors discussed the results and contributed to the final manuscript.

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Bài Nghiên cứu

Sử dụng ảnh vệ tinh Landsat cho đánh giá thay đổi đường bờ tại khu vực Sông Tiền và Sông Hậu tại tỉnh An Giang

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TÓM TẮT
Tỉnh An Giang là một vùng kinh tế trọng điểm của Đồng Bằng Sông Cửu Long cũng như là Việt Nam. Cùng với sự tăng trưởng của nền công nghiệp hóa và hiện đại hóa, An Giang gánh chịu những hậu quả thiên tai từ xâm nhập mặn, khô hạn, và xói mòn bờ sông do những tác nhân tự nhiên và con người. Trong số đó, sạt lở bờ sông là một vấn đề trọng yếu của An Giang, vì sự phát triển nhanh chóng của đập thủy điện và khai thác cát quá mức tại thượng nguồn đã dẫn đến sự thay đổi hình thái và những đặc điểm phù sa tại nơi này. Trong nghiên cứu này, chúng tôi điều tra thay đổi đường bờ bằng việc sử dụng hệ số phân tác nước trên nền tảng ảnh Landsat. Trong nhiều những chỉ số phân tác nước như Normalized Difference Water Index (NDWI), Modified Normalized Water Index (MNDWI), and Automated Water Extraction Index (AWEI), AWEI đã được xác định là chỉ số phù hợp cho khu vực nghiên cứu. Kết quả nhận định dựa vào bảng đánh giá khả năng phân tách nước tại bốn khu vực của tỉnh An Giang (Huyện An Phú, Vĩnh Hòa, Chợ Mới và Sông Vàm Nao). Dựa vào đó, AWEI được sử dụng để phân tách đường bờ cho khu vực nghiên cứu trong khoảng thời gian 1989-2015. Sau khi sử dụng phương pháp AWEI, LRR được ứng dụng để xác định tỷ lệ thay đổi của đường bờ. Nghiên cứu nhận định rằng tỷ lệ sạt lở bờ sông cao ở các khúc sông cong và phần đầu của cù lao điển hình như Tân Châu (-33m/năm), Chợ Mới (-36m/year) và Vam Nao (-3.07 m/year). Bên cạnh việc phân tích tỷ lệ sạt lở hằng năm, nghiên cứu cũng trao đổi một vài nguyên do sạt lở và phương pháp nhằm khắc phục tình trạng này. Nghiên cứu cho rằng nên có những giải pháp bền vững để giảm thiểu sạt lở tại An Giang.
Từ khoá: MNDWI, AWEI, NDWI, viễn thám, DSAS, thay đổi bờ sông, tỉnh An Giang

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