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A new method for river bank detection from Landsat satellite data in the context of the Vietnamese Mekong Delta

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Introduction

Dam construction and sand mining activity in the Mekong river and its tributaries resulted in a drastic decrease in sediment discharge in the Vietnamese Mekong Delta (VMD). This reduction affects in turn the river bank (RB) erosion process.

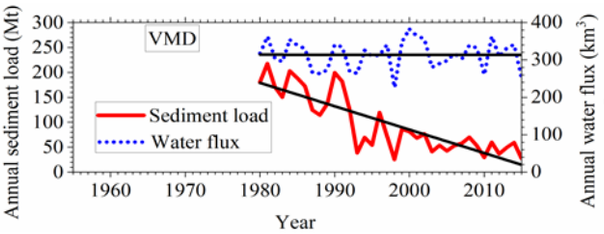

Fig. 1: Water and sediment discharge evolution in the VMD (Binh et al., 2020)

Fig. 2: River bank erosion in the upper part of the VMD

Methodology development

The new RB detection method is based on known concepts which have been modified and combined in order to be suitable for the complex context of the VMD. For its development, 11 RB detection methods were compared to one another. Their computation can be divided into 2 steps.

Segmentation method	NDVI	NDWI	MNDWI	WNDWI	$AWEI_{nsh}$
Default thresholding	X	X	X	X	X
Otsu method	X	X	X	X	
M-AMERL		X	X		

Tab. 1: Combination of 3 land-water segmentation methods with 5 spectral indices

Step 1: Calculation of spectral indices

Land cover types have different reflectance values per wavelength range. Spectral indices are based on this characteristic and are the combination of specific satellite bands. Their goal is to increase the discrepancy between water and land. The analyzed indices are NDVI, NDWI, MNDWI, WNDWI. and $AWEI_{nsh}$.

Step 2: Land-water segmentation

The pixels of the spectral indices were classified as land or water using 3 different approaches: default thresholding, Otsu's segmentation method and a method based on mathematical morphological techniques (M-AMERL). The former two are classic image segmentation methods from the literature. M-AMERL works with the watershed algorithm applied over the image gradient. The watershed algorithm treats the input image like a topographic map and finds the line along the ridges.

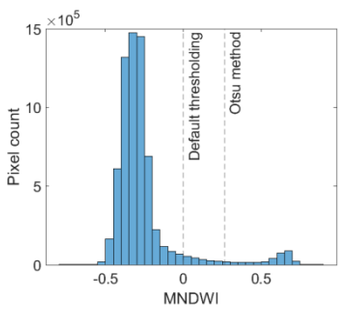

Fig. 3: Image segmentation thresholds

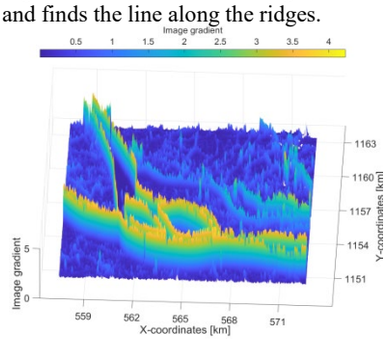

Fig. 4: Image gradient over study area

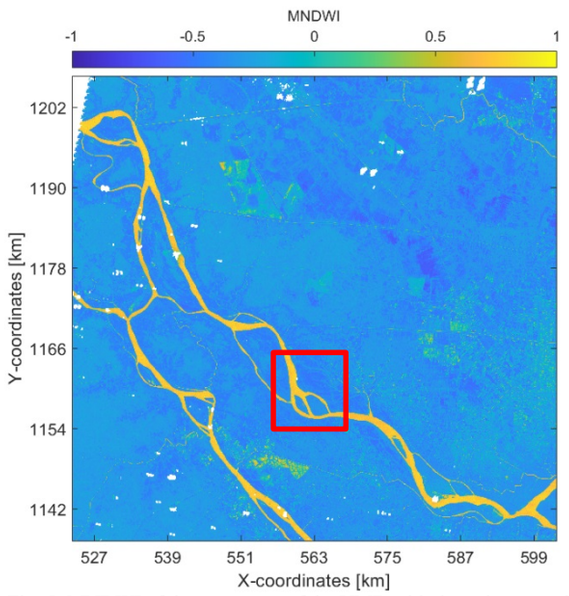

Fig. 5: MNDWI of the upper part of the VMD with the red surrounded study area

Increase accuracy with a Spectral Mixture Analysis (SMA) of the RB pixels:

SMA based on a Linear Spectral Mixture Model (LSMM) is used to increase the accuracy of the best performing RB detection method. LSMM allows to estimate the water fraction α contained in a mixed water-land pixel and to shift the detected RB accordingly. R_{mix} stands for the spectral value of the mixed water-land RB pixel. R_w and R_l are the most representative spectral values for water and land respectively. This values are calculated based on the average of the surrounding pure water and pure land pixels. These are identified based on thresholds given in the literature.

$$R_{mix} = \alpha * R_w + (1 - \alpha) * R_l$$

Results

NDWI combined with M-AMERL segmentation technique showed the best results. This is mainly due to the fact that it is not only based on the spectral characteristics of the pixels but also on their topological connections.

SMA combined with $NDWI_{M\text{-}AMERL}$ increases the mean accuracy of the surface change estimation between two data sets by around 40% when it is compared to the most popular RB detection methods based on spectral indices (NDWI and MNDWI combined with default thresholding or Otsu's segmentation method). Compared to WNDWI and $AWEI_{nsh}$ the accuracy is increased by around 30%. NDVI is not suitable for an application in the VMD.

A big impact of water level fluctuations on the position of the land-water interface during dry season was observed. To analyze the RB erosion evolution in the VMD, further studies are therefore advised to work with satellite data collected during a period with intermediate water level (June to July).

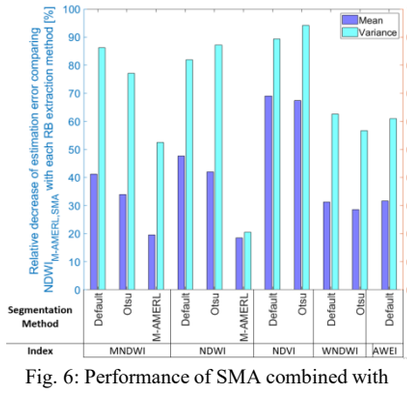

Fig. 6: Performance of SMA combined with $NDWI_{M\text{-}AMERL}$