INUNDATION IN THE LOWER MEKONG RIVER USING MODIS SATELLITE IMAGERY

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ABSTRACT

In this paper, MODIS satellite images corrected land surface reflectance 8-day and at 500 m spatial resolution are used to produce the time-series of inundated maps in the Lower Mekong River. Firstly, the methodology introduced by Sakamoto et al. [4] is applied to classify the flood, mixed and non-flood pixels in each image of 26 MODIS images collected between June 2000 and October 2001. Then, the inundated area is computed based on the number of flood and mixed pixels. The results showed that the obtained inundated maps for three given dates in year 2001 were comparable with the observed products of the Mekong River Comission. In the Mekong Delta, the variation of the inundated area during the period from June to December 2000 is in good agreement with the variation of the observed water elevation at the Tan Chau station, with the correlation coefficient is greater than 0.85.

Keywords: Lower Mekong River, Mekong Delta, MODIS imagery, inundated map, flood.

1. INTRODUCTION

The Lower Mekong River (LMR), home to more than 60 million people of Laos, Thailand, Cambodia and Vietnam, is the most important region in terms of both environment and economy. For instance, the Mekong Delta produces 50% of annual rice, 50% of fisheries and 70% of fruit production of Vietnam event its area covers only 12% of Vietnam [1]. However, the region is under the threat from a combination of human activities and various natural factors such as climate change and sea-level rise [2]. As reported by Mekong River Commission [3], 136 hydropower plants are being built or planned throughout the Mekong River Basin and these constructions for electricity production have caused large impacts on water resources in the region such as changes in the magnitude of flow, inundation processes. The frequency of tropical storms also has increased in La Nina years causing deadly and costly floods. The average annual cost of the repercussions of flood in the LMR ranges from 60 to 70$ million while the average annual value of flood benefits is approximately from 8 to 10$ million [3]. Reduction of the costs and impacts of flooding while preserving the benefits are thus still challenge.

Among different data resources and techniques, satellite remote sensing has been widenly used for detecting inundated areas in general and particular in the LMR [3, 4]. For instance, Sakamoto et al. [4] used the MODIS time-series imagery over the period from 2000 to 2004 to analyze the spatial and temporal changes in the extent of annual flooding within the Cambodia and the Mekong Delta. Pham-Duc et al. [5] ultilize the MODIS imagery and ENVISAT altimetry data are also applied to produce monthly variation of surface-water extent within the floodplains in Cambodia and Vietnam during the 2003-2009. These examples clearly demonstrate that

MODIS imagery can be used to build preciese maps of the flood extent that are often required for detecting deficiencies in existing flood control measures and for arbitrating damage claims. The main purpose of the present study is to build inundated maps resulted from different flow conditions in years 2000 and 2001 within the LMR based on MODIS/Terra satellite observations.

2. MATERIAL AND METHODOLOGY

The MODIS/Terra (MOD09) images corrected land surface reflectance 8-day and at 500 m spatial resolution of the study area are used to create inundated maps over the whole Mekong Delta. In detail, we used 26 MOD09 images in flood season of year 2000 and 2001, which have been archived in the MODIS/Terra satellite observations from NASA's Earth Data. These images are the images of high observation coverage, absence of clouds or cloud shadow [5].

To create surface-water extents as well as inundated maps resulted from high flows in the studied area, the methodology introduced by Sakamoto et al. [4] that was specifically designed and developed for tropical regions like the Mekong Delta, is implemented. Three water indices namely Enhanced Vegetation Index (EVI), Land Surface-Water Index (LSWI), and Different Value between EVI and LSWI (DVEL) are calculated for identification and classification of non-flooded and water-related pixels in each image. These indices are calculated as:

$$EVI = 2.5 \times \frac{NIR - RED}{NIR + 6 \times RED - 7.5 \times BLUE + 1} \quad (1)$$

$$LSWI = \frac{NIR - SWIR}{NIR + SWIR} \quad (2)$$

$$DVEL = EVI - LSWI \quad (3)$$

where *NIR*, *RED*, *BLUE* and *SWIR* are the surface reflectance value of near infrared Band 2 (841–876 nm), visible Band 1 (*RED*, 620–670 nm), visible Band 3 (*BLUE*, 459–479 nm), and short-wave infrared Band 6 (1628–1652 nm), respectively.

In terms of classification when using the methodology mentioned-above, all pixels with *EVI* values ≥ 0.3 are classified as non-flooded pixels. Water-related pixels are marked when the *DVEL* values ≤ 0.05 and the *EVI* values ≤ 0.3. If a pixel has its *EVI* value ≤ 0.05 and its *LSWI* value ≤ 0, it is also marked as a water-related pixel. At the final step, a threshold on the *EVI* values is used to distinguish between mixed pixels and fully inundated pixels from water-related pixels. Mixed pixels are defined as pixels that are partly inundated. The *EVI* values in open-water bodies such as lakes or oceans are normally low, therefore, if *EVI* values ≤ 0.1, these water-related pixels are set as the fully inundated pixels. If the *EVI* values > 0.1 and ≤ 0.3, then these water-related pixels are marked as the mixed pixels. General flowchart of the methodology is shown in Fig. 1.

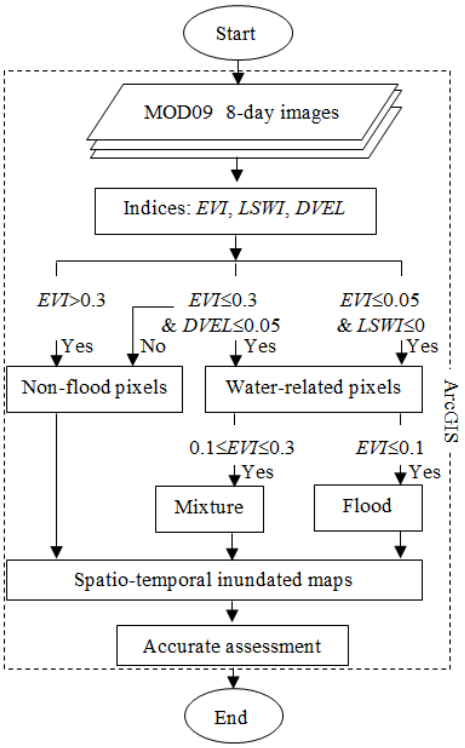

Fig. 1 General flowchart of the methodology to create inundated maps

3. RESULTS AND DISCUSSION

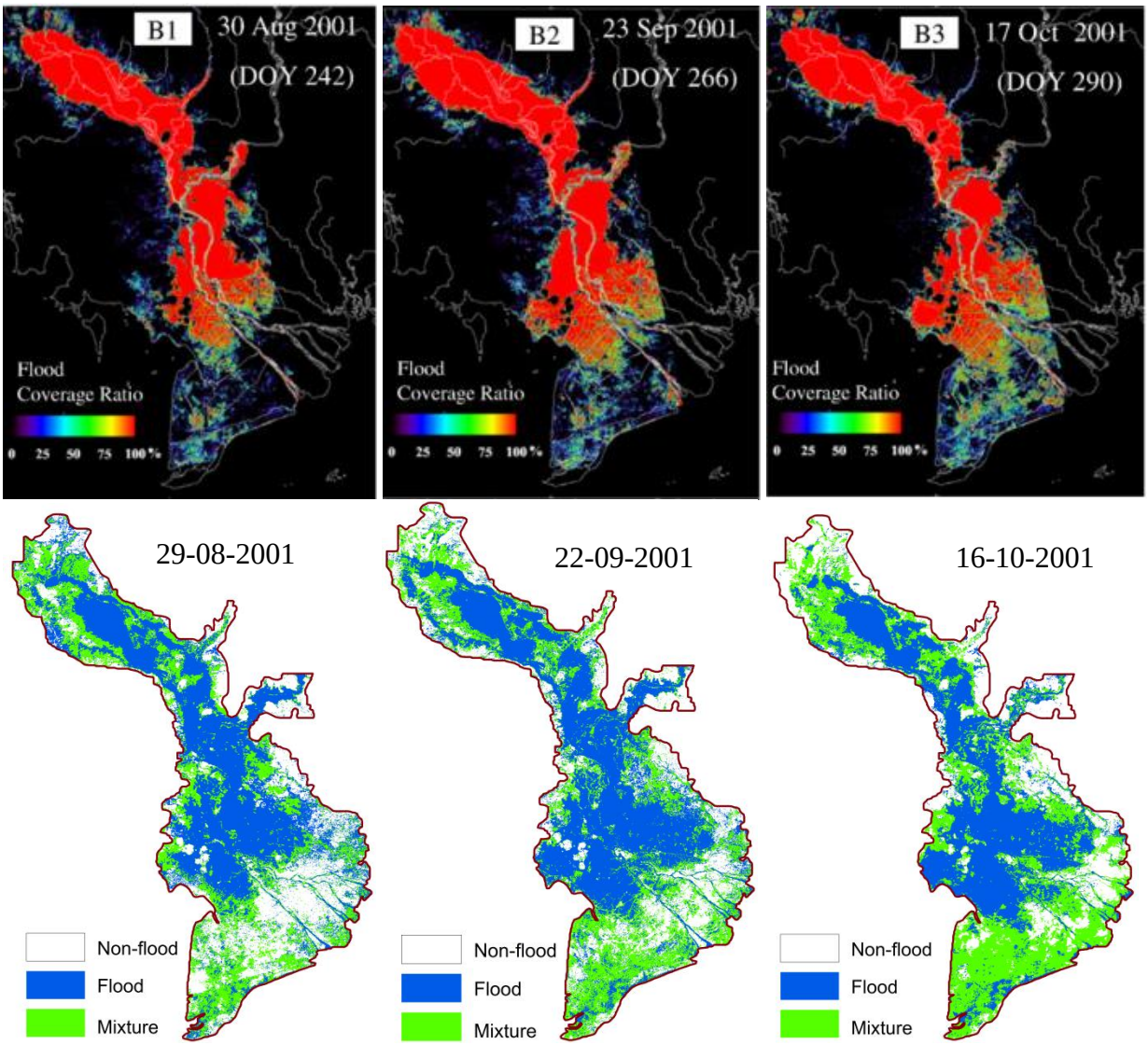

Fig. 2 Examples of inundated maps in the lower Mekong River when using MODIS images at 500 m spatial resolution: MRC products (top panels [4]) and the present study (down panels)

Fig. 2 shows the surface water extents or inundated maps in the LMR when using the MODIS images at 500 m spatial resolution on different dates, i.e. 29-08-2001, 22-09-2001 and 16-10-2001. It is observed that large water bodies are clearly detected when using MODIS images. The surface water extent shows an increase trend when increasing the water elevation. On the other hand, the surface water extent obtained from the present studies depicts clearly trend in comparison with the inundated maps produced by the Mekong River Commission. These results suggest that the methodology using in this study is acceptable.

Fig. 3 shows the time-series of inundated areas resulted from all flood pixels within the Mekong Delta and observed water elevation at the Tan Chau station for the period from June to December 2000, while Fig. 4 depicts the time-series of inundated area resulted from flood pixels and 25%, 50% and 75% of mixed pixels. The correlation coefficient between the inundated areas and the observed water elevations is 0.86, 0.87, 0.88 and 0.88 for the case of flood pixels, flood

pixels plus 25% mixed pixels, flood pixels plus 50% mixed pixels, and flood pixels plus 75% mixed pixels, respectively. These results reveal that the variation of the inundated area within the Mekong Delta is in good agreement with the variation of the observed water elevation at the Tan Chau station. This result is consistent with the results reported in the previous studies [4, 5].

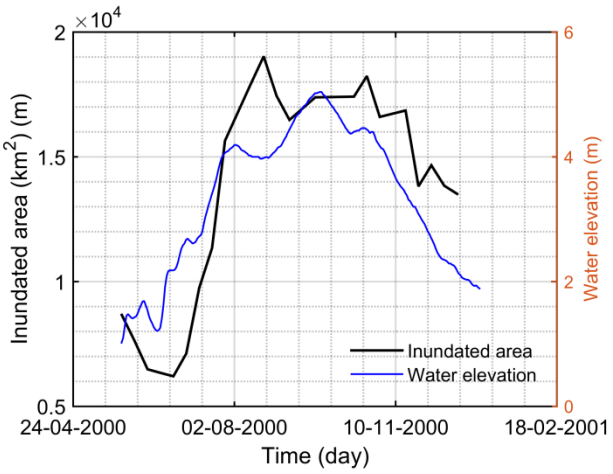

Fig. 3 Time-series of inundated area in the Mekong Delta (from flood pixels)

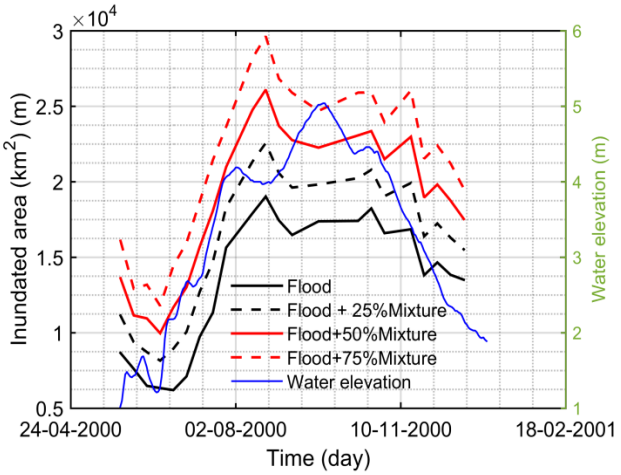

Fig. 4 Time-series of inundated area in the Mekong Delta (from flood pixels and different percentage of mixed pixels)

4. CONCLUSION

MODIS satellite imagery provides a unique source of data given its spatial and temporal coverage, with different level of detail that can be used to produce inundated maps for detecting deficiencies in existing flood control measures as well as for arbitrating damage claims in the river basin. Using the methodology introduced by Sakamoto et al. [4] to classify the flood, mixed and non-flood pixels in each MODIS image, inundated maps in the LMR and Mekong Delta during the period from June 2000 to October 2001 were produced and presented. The results clearly demonstrated that the obtained inundated maps were able to use in monitoring surface water extents resulted from different flow conditions in the domain of interest.

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