EXPLORING LST CHANGES IN THE VIETNAMESE MEKONG RIVER DELTA WITH 2000 - 2015 MODIS DATA

Vu Phan-Hien*, Ngan Nguyen-Truong, Khanh Nguyen-Trong, Khanh Chau-Phuong

Department of Geomatics Engineering, Faculty of Civil Engineering, University of Technology – VNU-HCM
268 Ly Thuong Kiet Street, Ward 14, District 10, Ho Chi Minh City, Vietnam
Email: phanhienvu@hcmut.edu.vn

ABSTRACT

During the last decades, the land-use structure in the Vietnamese Mekong River Delta has changed due to industrialization. Recently a trend of built-in areas increases while vegetable areas have a decrease trend. These make land surface temperature (LST) increase in urban and industrial areas, and several bare soil areas. The paper focuses on exploiting MODIS data to determine a spatial pattern of LST changes from 2000 to 2015. For each pixel, the trend of LST changes has been estimated by a linear regression. The results indicate that generally LST in the Vietnamese Mekong Delta increase at an average rate of +0.1 ^{0}C per year between 2000 and 2015. Most of the central areas have an increased trend of the LST changes, to be indicative of becoming warmer, occupying about 45% of the total area. Inversely, the maritime provinces have few areas becoming cooler, shown by negative trends of the LST changes, occupying approximately 5%.

1. INTRODUCTION

The Vietnamese Mekong River Delta is located in the lower Mekong River, with a fairly flat terrain and an intricate network of canals. However, due to the impact of industrialization and population growth, its land-use / land-cover has changed significantly over the years. It directly affects agricultural production and ecosystem of this region. Additionally, it makes land surface temperature (LST) changed as well. In fact, drought has appeared sparsely in this region during the last decades.

LST is one of important factors using to assess effects of environment and climate change human living and production activities, practically for monitoring drought. At present, for monitoring LST the remote sensing technique shows many advantages than the method of measurements from ground observation stations (Zargar et al., 2011). Using temperature data from meteorological stations is highly dependent on surface interpolation, size and distribution of input sample points, while many remote sensing data sources provide global and daily information. Popular thermal image sources, free of charge, are captured from satellites Landsat, MODIS, or NOAA. Thus, the purpose of this work is to exploit if MODIS data in the dry seasons from 2000 – 2015 can be used to monitor LST change in the Vietnamese Mekong River Delta.

2. DATA AND METHOD

2.1 Study Area

The Vietnamese Mekong River Delta is located in the south of Vietnam. It borders

Cambodia in the north and northwest and Gulf of Thailand in the west and southwest. This region is considered as an important geopolitical area for international shipping lanes between South Asia and East Asia as well as with Australia and other islands within Pacific Ocean. Figure 1 shows the administrative map of the Vietnamese Mekong River Delta.

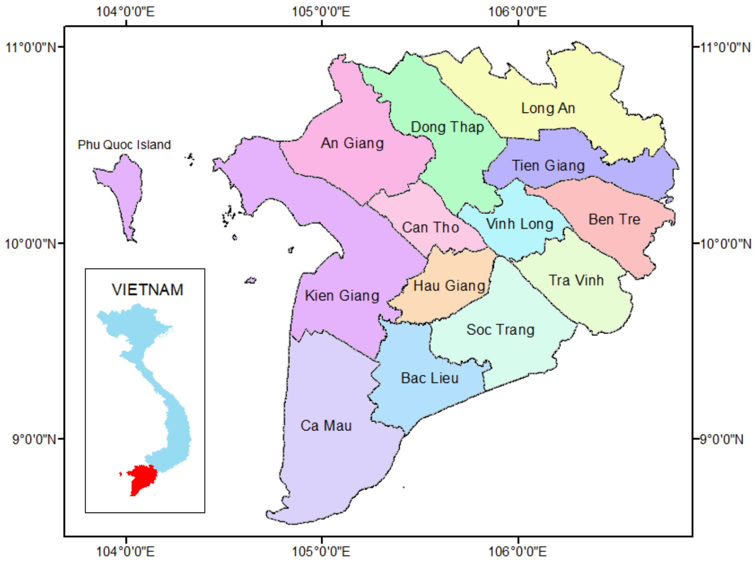


Figure 1. Administrative Units of the Vietnamese Mekong River Delta

2.2 Data

Main data sources used to compute LST are derived from the MOD09GQ and MOD021KM data products. The USGS provide these data products free of charge. MOD09GQ provides MODIS band 1-2 daily surface reflectance at 250 m resolution (Vermote et. al., 2015), where band1 covers a spectral range of 0.62 – 0.67 μm and band2 of 0.84 – 0.87 μm. These reflective data are used to compute NDVI. MOD021KM provides MODIS band 31-32 daily thermal emission at 1 km resolution (Hulley et. al., 2017). These emissive data in a combination with NDVI are used to compute LST.

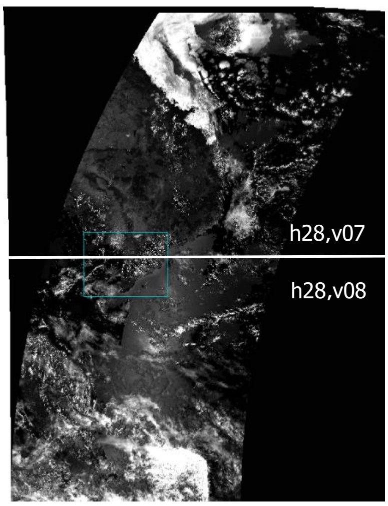


Figure 2. Two scenes of MODIS images at the locations of 'h28v07' and 'h28v08'

The observed period is the dry seasons, from January to April, between 2000 and 2015. To cover the whole Vietnamese Mekong River Delta, we need two scenes at the locations of 'h28v07' and 'h28v08', as shown in Figure 2. The couple of the two scenes were captured nearly at the same time. The images are referenced to the Sinusoidal datum, and stored in the hdf format. In this study, the downloaded data include 315 image couples in case of less than 10 percentage of cloud cover during the observed period.

2.3 Method

In this section, we describe the processing of the MODIS data to estimate temporal trends of LST changes in dry seasons between 2000 and 2015. Firstly, the MODIS dataset are pre-processed. For each image acquisition time, NDVI is determined from the MOD09QG 1-2 reflective bands. Then, LST is derived from the MOD021KM 31-32 emissive bands and the NDVI image. Finally, for each pixel a temporal trend of LST changes during the observed period is estimated based on a linear regression. This resultant image is expected to be representative for a state of LST change in the study area.

2.3.1 Pre-processing

The pre-processing of the input data consists of steps such as two scene mosaicking, layer stacking, coordinated system converting, and spatial subset making. Firstly, two scenes of images are merged to cover the whole observed region. Then, bands 31, and 32 are combined to store into one file. Subsequently, the data set of images is converted to the WGS84 geographic coordinate system. Finally, the images are clipped following to the boundary of the Vietnamese Mekong River Delta.

2.3.2 NDVI

Based on Red and NIR reflective bands, NDVI is determined as in equation (1). Here, Red and NIR are representative for the MDO09QG band 1 and 2 surface reflectance values respectively. Figure 3a) shows NDVI derived from the data on 12 Feb 2015.

$$NDVI = \frac{NIR - Red}{NIR + Red} \tag{1}$$

2.3.3 LST

Based on the algorithm developed by (Price, 1984) and confirmed by (Vazquez et al., 1997), LST is computed following equation (2). Here, T_{31}, T_{32} (K) are the brightness temperatures obtained from band 31, band 32, respectively. And, ε_{31}, ε_{32} are the surface emissivity coefficients in band 31, band 32, respectively. In addition, the surface emissivity is calculated from NDVI, applying the algorithm developed by (Cihlar et al., 1997), as equations (4) and (5). Figure 3b shows LST derived from the data on 12 Feb 2015.

$$LST = T_{31} + 1.8(T_{31} - T_{32}) + 48(1 - \varepsilon) - 75\Delta\varepsilon \tag{2}$$

$$\varepsilon = (\varepsilon_{31} + \varepsilon_{32})/2 \tag{3}$$

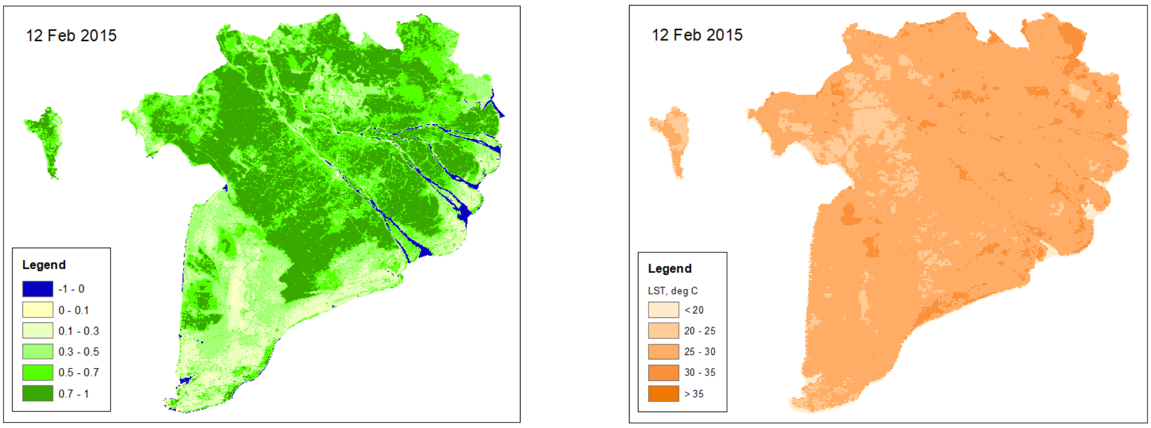
$$\Delta\varepsilon = \varepsilon_{31} - \varepsilon_{32} = 0.01019 + 0.01344 ln(NDVI\ ) \tag{4}$$

$$\varepsilon_{31} = 0.9897 + 0.029 ln(NDVI) \qquad (5)$$

The brightness temperature detected by a thermal sensor T_b is determined by Planck's equation (6).

$$T_b = \frac{hc/k\lambda}{\ln\left(\frac{2\pi hc^2\lambda^{-5}}{L_\lambda} + 1\right)} = \frac{K_2}{\ln\left(\frac{K_1}{L_\lambda} + 1\right)} \qquad (6)$$

Where, L_λ ($Wm^{-2}sr^{-1}\mu m^{-1}$) is the spectral radiation, $h = 6.62x10^{-34}$ (Js) is Planck's constant, $c = 3x10^8$ (ms^{-1}) is the speed of light, $k = 1.38x10^{-23}$ (JK^{-1}) is Boltzman's constant, and λ (μm) is the central wavelength. K_1 and K_2 ($Wm^{-2}sr^{-1}\mu m^{-1}$) are called calibration coefficients, for band31: K_1 = 730.01, K_2 = 1305.84, and band32: K_1 = 474.99, K_2 = 1198.29 (Hong et al., 2005).



a) b)

Figure 3. a) NDVI and b) LST in the Vietnamese Mekong River Delta on 12 Feb 2015

2.3.4 A temporal trend of LST change

Based on the dataset of the LST images, a spatial pattern of LST changes in the study area between 2000 and 2015 is estimated by a linear regression. It means, for each pixel, a temporal trend of LST change during the observed period is determined. A rate of LST change is described as the slope of a fitting line estimated from LST values in time-series. Thus, the resultant image shows a state of LST change in the whole study area.

3. RESULTS AND DISCUSIONS

A spatial pattern of the LST changes in the Vietnamese Mekong River Delta during the dry seasons from 2000 to 2015 is shown in Figure 4, in which each pixel presents a temporal trend of LST changes. Each pixel is classified into one of five colored groups, based on its rate of the LST changes. The total area of the yellow pixels occupies about 50% of the study area, meaning rates of the LST changes are approximately zero per year. The blue-tone pixels, occupying the total area of about 5%, present a negative trend of the LST changes, while the red-tone pixels, also occupying the total area of about 45%, show a positive trend of the LST changes. Most of areas having an increased trend appear in the center of this region, including provinces such as Tien Giang, Dong Thap, Vinh Long, Can Tho, Hau Giang, and Ca Mau. This means that these areas are prone to increased temperature or warmer level. On the other hand, the provinces having a maritime boundary have a decreased trend of the LST changes. These areas can be cooler. In general, LST in the Vietnamese Mekong Delta increase at an average rate of +0.1 ^{0}C per year between 2000 and 2015. The total areas of rates of the LST changes in the Vietnamese Mekong River Delta in the observed period are shown in Table 3.

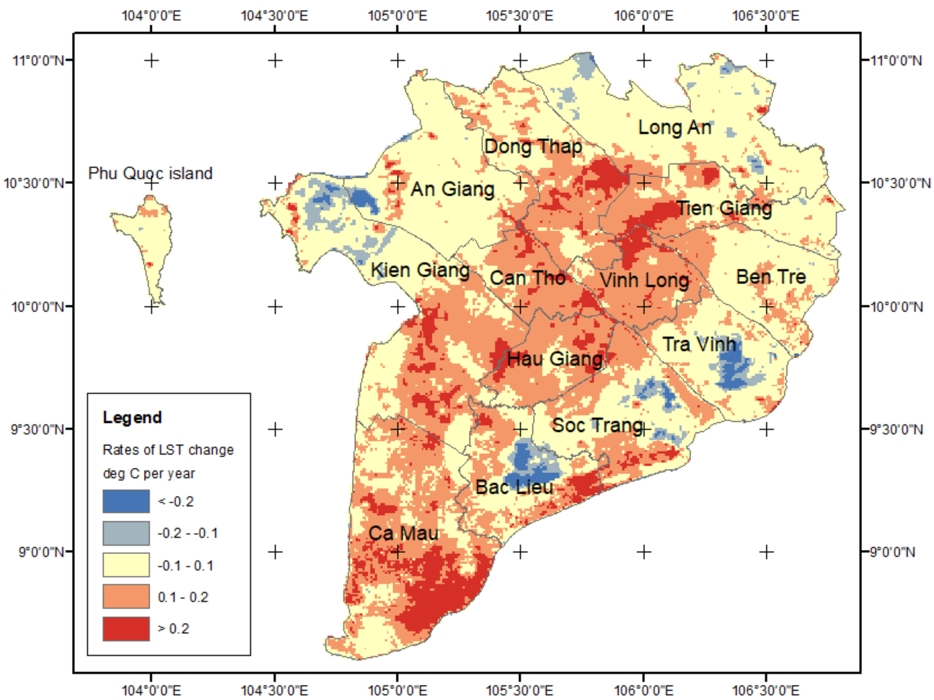


Figure 4. Rates of LST changes in the Vietnamese Mekong River Delta in dry seasons from 2000 to 2015

Table 3. Areas of rates of LST changes in the Vietnamese Mekong River Delta in the 2000 – 2015 dry seasons.

Rates of LST change per year	≤ -0.2	-0.2 - -0.1	-0.1 - 0.1	0.1 - 0.2	> +0.2	Total area (km²)
An Giang	74	51	2959	414	44	3542
Ben Tre	3	13	1668	646	23	2351
Bac Lieu	190	197	976	929	186	2478
Ca Mau	0	5	1486	2583	1196	5270
Can Tho	0	0	294	955	188	1437
Đong Thap	0	2	1465	1559	358	3383
Hau Giang	0	0	252	1129	236	1617
Kien Giang	45	413	3305	2120	431	6314

Long An	12	272	3870	361	33	4546
Soc Trang	60	216	1648	1256	128	3307
Tien Giang	0	14	1266	909	244	2433
Tra Vinh	150	219	1616	379	7	2371
Vinh Long	0	0	122	1205	221	1549
VN Mekong River Delta (Km^2)	534	1401	20926	14445	3294	40600
Percentage (%)	1.32	3.45	51.54	35.58	8.11	100.00

4. CONCLUSION

The results present that a state-of-the-art analysis of LST occurred in the Vietnamese Mekong River Delta in the dry seasons from 2000 to 2015. In general, LST in the Vietnamese Mekong Delta increase at an average rate of +0.1 ^{0}C per year between 2000 and 2015. Most of the central areas have an increased trend of the LST changes, to be indicative of becoming drier. Inversely, most of the maritime provinces have serval areas becoming wetter, shown by negative trends of the LST changes.

ACKNOWLEDGMENT

This work was supported by the Vietnam National University – Ho Chi Minh City, Project No. C2017-20-21

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