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The temperature vegetation dryness index from satellite image support monitoring drought in a territory

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Abstract

Climate change has attracted whole the world's interest with the increasing temperature of the Earth's surface. The consequence of this problem is the drought increasing, affected strongly to human life and socio-economic development. This paper presents the result of application of remote sensing technology in drought assessment in dry season from 2011 to 2015 (from November to April in the following year). The study has used MODIS imageries of 8-day composite, MOD9A1 with 500 m resolution and MOD11A2 with 1 km resolution. The average of the temperature vegetation dryness index (TVDI) of Southeast is from 0.50 to 0.63. It tends to increase from the beginning to the end of dry season, and higher in the following years. The average TVDI in Southeast generally tends to increase by time and to be inversely proportional to precipitation. The errors assessment shows a high correlation between the calculated results and the measured data of temperature and precipitation from meteorological station in the study area (R>0.7). The study results will be a good reference to contribute to monitoring temporal and spatial drought evolution in the Southeast region under climate change now, aims to serve the sustainable environmental planning and management to ensure the community safety.

Keywords: climate change, drought, MODIS, precipitation, TVDI

1. Introduction

Currently, the state of climate change globally is increasing dramatically and the serious negative consequences due to the impact of climate change on the earth is huge, express in a concrete way by the phenomenon such as rising sea levels, melting ice, heat, floods, epidemics, economic losses, reduced biodiversity, ecosystem destruction and drought in many areas. Drought is a regular phenomenon appears and occurs in most of the different geographical regions. Droughts often influence on the extensive and seldom directly cause loss of life, but the damage caused by drought is huge. Drought is a process that goes on for a long time and on a large scale, so as to undertake research on this issue should have methods to meet these requirements. In many current methods, the use of remote sensing to study this issue has a lot of potential, so satellite images have been able to provide useful information on a wide range of areas and cyclical observation by flight orbit. In addition, remote sensing is a technique still prominent than the conventional method in the evaluation process through the ability to provide information quickly and at a reasonable cost. Therefore, the application of remote sensing in the study of drought is a perfect fit. This technology can assist in the study of

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the surface temperature to monitor the evolution of drought, to support the warning, develop policies for sustainable management of the environment in the present and the future.

Objective of the study was to determine drought conditions for a territory on the basis of remote sensing applications through the drought index. The study area Southeast comprises 06 provinces and 1 city with 23 564 km^2 natural area (Information in rural Vietnam, 2016). These are areas where geography stretching from the southern coast to the northern areas of high terrain. In addition to the impact of sea level rise, it is also affected by the risk of drought, especially in areas of high terrain to the north (Fig. 1). Time studies surveyed in the dry season period from 2011 to 2015.

Fig. 1. The study area

2. Methodology

2.1. Land surface temperature (LST). LST are extracted from MOD11A2. The effects are corrected by the split window algorithm; consider that the difference of signal in the two bands TIR is due to differences in the absorption of radiation in the atmosphere (Meng Guo et al., 2012). The conversion ratio is supplied from the manufacturer through the technical parameters were calculated based on the experiment when use of algorithms to determine the temperature from a variety of methods. Land surface temperature is determined by multiplying the value of the image after separating layer, and adjusted coordinates with the conversion "Scale Factor = 0.02" to get the Kelvin (K) and then converted to the Celsius temperature (^{o}C).

$$\text{LST (K)} = \text{pixel value on LST image} * 0.02 \quad (1)$$

2.2. Normalization Differences Vegetation Index (NDVI). NDVI in this study were calculated indirectly through 7 bands of MODIS, MOD09A1. NDVI is calculated by the following formula*:*

$$\text{NDVI} = (\text{NIR}-\text{R})/(\text{NIR}+\text{R}) \quad (2)$$

Where, NIR, R - corresponding to the MODIS spectral reflectance in band 2 and 1. The variation of NDVI depends on many factors, including reflections from the ground and the structure of the plant canopy. Besides certain canopy density, the increase of green biomass, chlorophyll also leads to a change of NDVI

2.3. *Temperature vegetation dryness index (TVDI).* The study conducted by Sandholt et al. (2002) found that there were many isoclines in the feature space of Ts-NDVI. After simplifying the feature space into triangle shape, they proposed the TVDI, an index based on the empirical interpretation of the NDVI–Ts triangle (Fig. 2). The TVDI is calculated using following equation:

$$\text{TVDI} = \frac{T_s - T_{s_{min}}}{a + b\text{NDVI} - T_{s_{min}}} \quad (3)$$

Where, T_s is the observed surface temperature at a given pixel (another called name LST); NDVI is the observed normalized difference vegetation index; a and b are the intercept and slope of the dry edge (the upper straight line in the triangle) calculated from the NDVI-T_s space regression with small intervals of NDVI (T_{smax}= a + b*NDVI), where, T_{smax} is the maximum surface temperature observation for a given NDVI value. The lower horizontal line of the triangle represents the wet edge (T_{smin}), which was calculated by averaging a group of points in the lower limits of the scatterplots (Son et al.2012). The TVDI values range from 0 to 1. TVDI=1 at the dry edge, indicating no evaporation from the soil or limited moisture supply; and TVDI=0 at the wet edge, indicating maximum evaporation from the soil or unlimited moisture supply.

2.4. Data.

(1) MOD09A1: is produced by the MODIS on the reflective surface, providing the first 7 channels (from channel 1 to channel 7) with a spatial resolution of 500 m, resolution time is 8 days. In this study, MOD09A1 used to calculate NDVI to serve the process of calculating the drought index TVDI. (2) MOD11A2: Ts is extracted from the product MOD11A2 used to calculate the TVDI. MOD11A2 are products containing layers MODIS surface temperature data (LST), photographed 8 day cycle, spatial resolution of 1 km. MOD11A2 contain many layers of data, to extract the necessary data layer; the researchers used MODIS Reprojection Tool software. Data provided MOD11A2 MOD09A1 and free from the website http://reverb.echo.nasa.gov/ (3) Insitu hydrometeorological data: Includes temperature data and the average monthly

rainfall in the dry season 6 month period from 2011 to 2015 from 8 stations meteorological observation offered by Hydro-Meteorological Observatory Southern region, used to verify the results. This data set was collected in parallel at the same time when the satellite image was aquisited.

3. Results and Discussion

Drought theory comes from the study of the interrelationship of NDVI and land surface temperature. TVDI drought index reflects plant conditions and the soil moisture of the area. In conditions of high surface temperatures and low rainfall, soil moisture will decrease, leading to a vegetative state will be sparse. The TVDI values range from 0 to 1, where TVDI = 1 at the dry edge, indicating no evaporation from the soil or limited moisture supply; and TVDI = 0 at the wet edge, indicating maximum evaporation from the soil or unlimited moisture supply. The TVDI is categorized into five classes describing drought conditions: (1) wetness (0–0.2); (2) normal (0.2–0.4); (3) slight drought (0.4–0.6); (4) moderate drought (0.6–0.8); and (5) severe drought (0.8–1) (Wang et al., 2004)

3.1. Temporal variation of TVDI

In the period 2011-2015, the whole region has a maximum value TVDI are in serious drought level from 0.87 to a maximum of 1, only 2 months are April 2012 and December 2014 with maximum TVDI lower than 0.9, the remaining months are most TVDI maximum value greater than 0.9. Especially the end of the dry season 2014-2015, the value reached the maximum drought (TVDI = 1) during 4 months. In terms of average, monthly average TVDI values achieved highest to 0.63, in moderate drought threshold. Table 1 lists the average value TVDI season across the southeastern region, showed that they are at a slight drought and in danger of reaching the threshold of moderate drought (TVDI = 0.57), not significantly fluctuate from 0.50 to 0.59. Especially in the dry season 2014-2015 TVDI values have fluctuation strongest when the difference between the maximum value and minimum reached 0.11, that the first season with the lowest value is 0.52, until the end of the season reaches the highest value is 0.63, and it has increased steadily over the dry season. In the dry season 2011-2012 and 2012-2013 there are the lowest fluctuations of the TVDI values when the difference was only 0.05

Table 1. The average TVDI value in the dry months of the period 2011 - 2015 across the Southeastern region

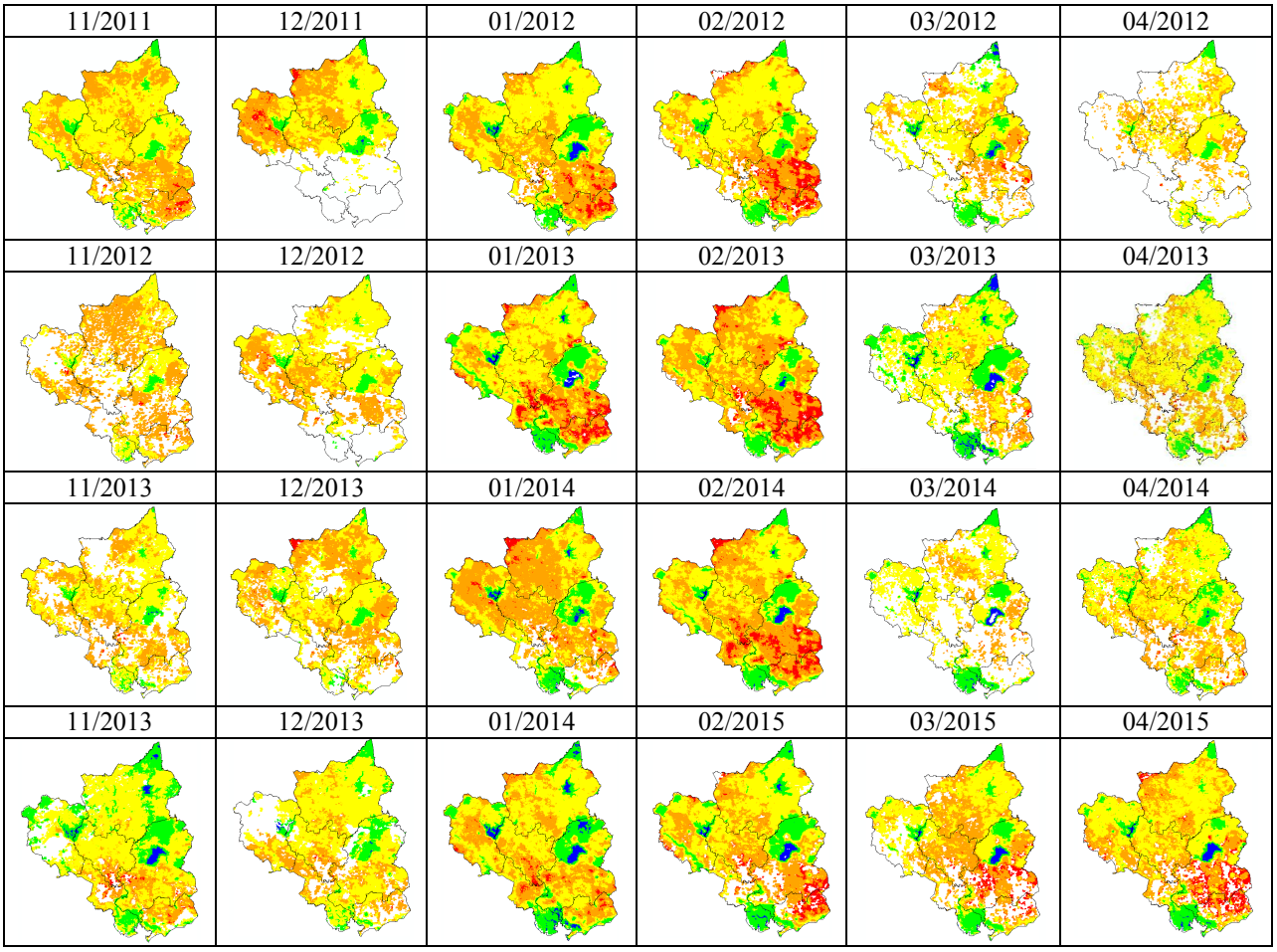
Month	Period				
	2011-2012	2012-2013	2013-2014	2014-2015	Mean
11	0.57	0.61	0.56	0.52	0.57
12	0.55	0.58	0.57	0.57	0.57
01	0.57	0.57	0.57	0.56	0.57
02	0.58	0.61	0.59	0.56	0.59
03	0.53	0.56	0.57	0.60	0.57
04	0.55	-	0.50	0.63	0.56
Mean	0.56	0.59	0.50	0.57	0.57
Max	0.58	0.61	0.59	0.63	
Min	0.53	0.56	0.50	0.52	
Bias	0.05	0.05	0.09	0.11	

3.2. Spatial variation of TVDI

Survey spatial distribution of TVDI index shows that South East region has most of the area is in drought levels from slight to severe drought. In the first two dry seasons 2011 - 2013, November is the month with the distribution area of moderate drought region accounted for the highest proportion, accounting for about 1/3 of the whole area and tends to shift to the end of the dry season, to April in the final phase from 2014 to 2015. Meanwhile, the severe drought that covers the area with a maximum area reached nearly 10%, the majority occurred in February every year. This shows that there is consistency between the distribution of drought in time and space from 2011 to 2015. Time occurs moderate and severe drought lasted until the end of the dry season (with interval 4 months late season with maximum TVDI = 1) of the area of severe drought space also expanded.

Considering the drought spatial distribution (Fig. 2) the area that has the TVDI index reached the average level at lowest are areas not at risk of drought (<0.4), accounting for about 10% of the whole area. They focus mainly in areas where the vegetation cover much or surface water as Can Gio mangrove forest located in Ho Chi Minh City; primary forest in Binh Chau, Xuyen Moc district in the province of Ba Ria Vung Tau; Cat Tien National Park, Tan Phu district, Dong Nai province; Bu Gia Map National Park, Phuoc Long district, Binh Phuoc province; National Park Lo Go - Xa Mat, Tan Bien District Tay Ninh Province. Residential areas, urban areas or areas with no vegetation corresponding NDVI values from 0.2 to 0.4, the average TVDI index is in

ranges from 0.4 to 0.6, corresponding to slight drought areas, accounting approximately 25-50% of the whole area, as a number of residential areas, urban centers in Ho Chi Minh City and Binh Duong. The rest, most of the areas with high TVDI value (> 0.6) are in the areas of agricultural land in the post-harvest stage or not in season, coastal sandy, barren land without vegetation, areas high terrain and the area regularly during prolonged hot dry season. Besides, there are some small areas appear serious drought condition (TVDI > 0.8) is due to high surface temperatures undergone a sudden mutation in that region, leading to severe dehydration plant, moisture reducing strong. The region occupies an area of distribution of about 15% - 45% of the whole area



TVDI

("NaN" - at the location that has no value by satellite imagery with cloud cover at a rate too high)

NaN	0– 0,2	0,2–0,4	0,4–0,6	0,6–0,8	0,8 -1
	wetness	normal	Slight drought	Moderate drought	Severe drought

Fig. 2. Map of the decentralization of the drought level combinations according to the dry months in the period 2011 - 2015

4. Conclusion

In recent years, the Southeast region is one of lack of water on a regular basis and drought is relatively heavy. From there, one can see that the research on drought alert is critical for responses, as well as land planning and distribution of irrigation systems accordingly. Results showed that in the Southeast region, the TVDI index tends uneven variation between regions. TVDI index, aggregated by the dry months, tends to increase gradually from the beginning of the dry season to the end of the dry season and next year is higher than last year. The entire area has high temperatures and transforms in a complex way. TVDI drought index was at slight to moderate drought, an area accounting for the highest proportion, accounting for about 1/3 of the whole area. TVDI maximum value lays in the serious drought from 0.87 to a maximum of 1 covered the area reaches nearly 10% of the whole area, the majority occurred in February every year. The initial findings of TVDI drought index, calculated from MODIS data will be an important basis for land use planning, rational use of resources, distribution of reasonable construction of the system irrigation systems, as well as help the government make planning, socio-economic development strategies and natural resource protection.

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