RESEARCH MEDIUM-RESOLUTION SATELITTE IMAGES FOR DROUGHT WARNING IN CENTRAL HIGHLAND, VIETNAM

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ABSTRACT

MODIS (Moderate Resolution Imaging Spectra radiometer) data, which have very large swath width of 2,330 km, high repetition frequency and average spatial resolution, is an objective method of obtaining information quickly and synchronously for large area. In Vietnam, Central Highland is one of the regions where drought and water shortage is the most serious in recent years. The object of this study is to assess the feasibility of medium resolution remote sensing data - MODIS in drought research for large region like Central Highland, and provide some initial drought warning for this area. Two products of MODIS – MOD11A2 and MOD09A1 were used in this study to calculate Temperature-Vegetation Dryness Index – TVDI. Correlation analysis showed a close relationship between land surface temperature and vegetation cover in this region. The Western part of Gia Lai province and Northwest part of Dăk Lak province have the highest drought indexes, which is in accordance with the situation of drought in recent years observed in the Central Highlands. The results revealed that TVDI is an useful index, can be applied in hydrological studies, and will be an accurate indicator for soil moisture. The findings from this study will be an important document for afforestation, forest conservation, and land use planning, and it'll help land managers in advising policy and strategies for economic development, as well as sustainable using of natural resources .

Introduction

A drought happens when a period of low rainfall leads to a shortage of water for a period of many months or many years in a certain area. In Vietnam, drought effect strongly on the socio-economic, water resources and agricultural production as well. Central Highland is one of the regions where drought and water shortage is most serious in recent years, especially when climate change occurs. Therefore, research about drought warning in this region is essential for responding and land-use planning, and sustainable using natural resource also.

In compare with flood, drought causes stronger and longer consequences and it's very difficult to identify in early stage. Because of silent happens and obstacle in visual observation of drought, traditional meteorological monitoring methods get many hindrance, particularly in developing countries. However, the remarkable advantages of remote sensing technology has now demonstrated, application of this technology in the field of drought research is entirely feasible. MODIS images (Moderate Resolution Imaging Spectra radiometer), which have very large swath widths of 2,330 km, high repetition frequency and average resolution, is a objective method of obtaining information quickly and synchronously for large area, that's why this kind of data will be very pertinent for drought monitoring in Central Highland. In addition, a major advantage of MODIS imagery is the availability of a suite of products ranging from raw images to highly processed products such as land surface temperature, vegetation indices, surface evaporation..which can be used for calculating drought indicator.

Previously, researchers have proposed many indicators and models using remote sensing data for drought monitoring, such as VCI (Vegetation Condition Index - the index of plant conditions) (Kogan, 1990) , TCI (temperature condition Index - temperature indicator) (Kogan, 1995), CWSI (crop water Stress Index - only a shortage of water for crops) (Jackson, 1981), TVDI (temperature Vegetation Dryness Index - only temperature of dry vegetation) (Sandholt, 2002) or VTCI (vegetation temperature condition Index - the index of plant conditions - temperature) (Wang, 2001), etc. Each drought index has particular advantages, has been applied in many studíes of drought all around the world. Based on the features of study area, and characteristics of MODIS data as well, authors choosed TVDI index, calculated from land surface temperature and vegetation indices which are provided from MODIS products in this study. Proposed by Sandhold (2002), TVDI has been widely used because it is simple and fast to compute. Many scientists have used TVDI to monitor drought in China as Changyao Wang (2004), Jin-Chuan (2007), Chunqiang Li (2006); Lu Yuan (2007); Zhiqiang Gao (2011); Lin Sheng Huang (2011); Gao (2011); Liang Liang (2013); Bao Yuhai (2013); Chen Bin (2013). In Vietnam, Tran Hung (2007) also applied this index for the Indochinese peninsula, N.T.Son (2011) used TVDI for the downstream Mekong River.

The object of this study is to assess the feasibility of medium resolution remote sensing data - MODIS in drought research for large area like Central Highland, and provide some initial warning for drought in this area.

Study area and data

For the purpose of this research, MODIS-8 days, 500-m product (MOD09A1) and 8 day 1000-m land surface temperature products (MOD11A2) were obtained to retrieve time series of TVDI maps. TVDI is calculated basing on relationship between land surface temperature (LST) and vegetation index NDVI. Images in dry seasons from 2007 to 2013 were collected to process and compute TVDI, to see the distribution of drought over space and time adequately. Apart from MODIS data, research also used the forest cover maps in Highland of FIPI (Forest inventory and planning institute), rainfall, land surface temperature data from the meteorological stations in the study area

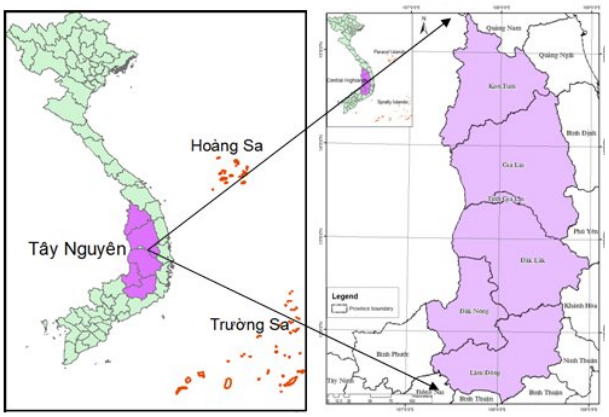

Figure 1. Study area

Study area is the Central Highlands, Vietnam, including five provinces. Geographically, the region is situated in the tropical monsoon area entirely, and due to its topography, climate in Highlands has two seasons: the dry season and the rainy one. The strong contrast between two seasons is supported by South Truong Son sierra, which is located perpendicularly to the wind direction with the effects of windbreaks. Thus, the typical weather of the rainy season is raining a lot, causing flooding, inundation, while having severe drought in dry season due to the lack of moisture. The rainy period is generally from May to October, it is cool and wet, favorable for crop and plant growing, whereas from November to April of next year, there is very little precipitation with low humidity and water shortages.

Method

Land surface temperature (LST) and vegetation index (NDVI) have quite clear inverse relationship (Sandholt et al 2002). So many drought indicator is calculated primarily based on this correlation. TVDI is also built by the method which quantify the relationship between LST and NDVI.

LST is retrieved from radiations of band 31, 32 (10.5 - 12.5 µm) of MOD11A2. This 1000m 8-day composite product shows the average LST. LST values were generated from known emissions for many kinds of material, by split-window algorithm. NDVI was used as an index of vegetation abundance, and was calculated by two first bands of MOD09A1. For the purpose of this research, MOD09A1 NDVI data were resized to 1000-m to match with LST images.

After interpretation the LST and NDVI correlation, Sandholt (2002) was the pioneer proposing TVDI index, basing on scatter plot (Ts, NDVI), to identify the soil moisture. The TVDI is estimated using the following equation:

$$TVDI = \frac{T_s - T_{s\min}}{T_{s\max} - T_{s\min}} = \frac{T_s - T_{s\min}}{a + b * NDVI - T_{s\min}} \quad (1)$$

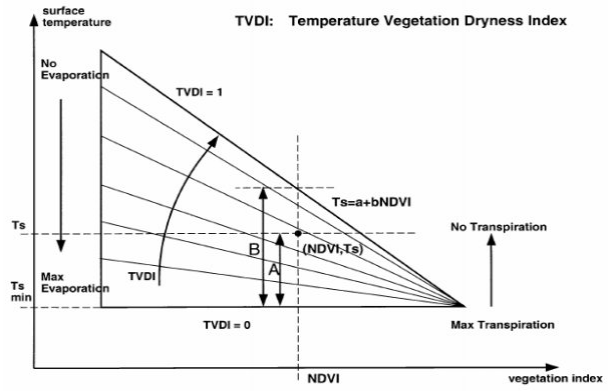

Figure 2. LST-NDVI triangle space in scatter plot [6]

Where Ts min which models the wet edge (figure 2) is minimum LST in LST-NDVI triangle of scatter plot, Ts is the observed LST at a given pixel, a and b are parameters defining intercept and slope of the dry edge. Two parameters were calculated from liner regression function of the maximum value of Ts for every range of NDVI values. Coefficients a and b are determined from the area which is large enough to represent full content of surface moisture. Theoretically, TDVI value is 1 in "dry edge" and 0 in "wet edge". The general trend of TVDI is having low values in rainy days, getting climax and many changes in dry season [6]. Its accuracy depends on how good two parameters are and cloud coverage ratio.

Results

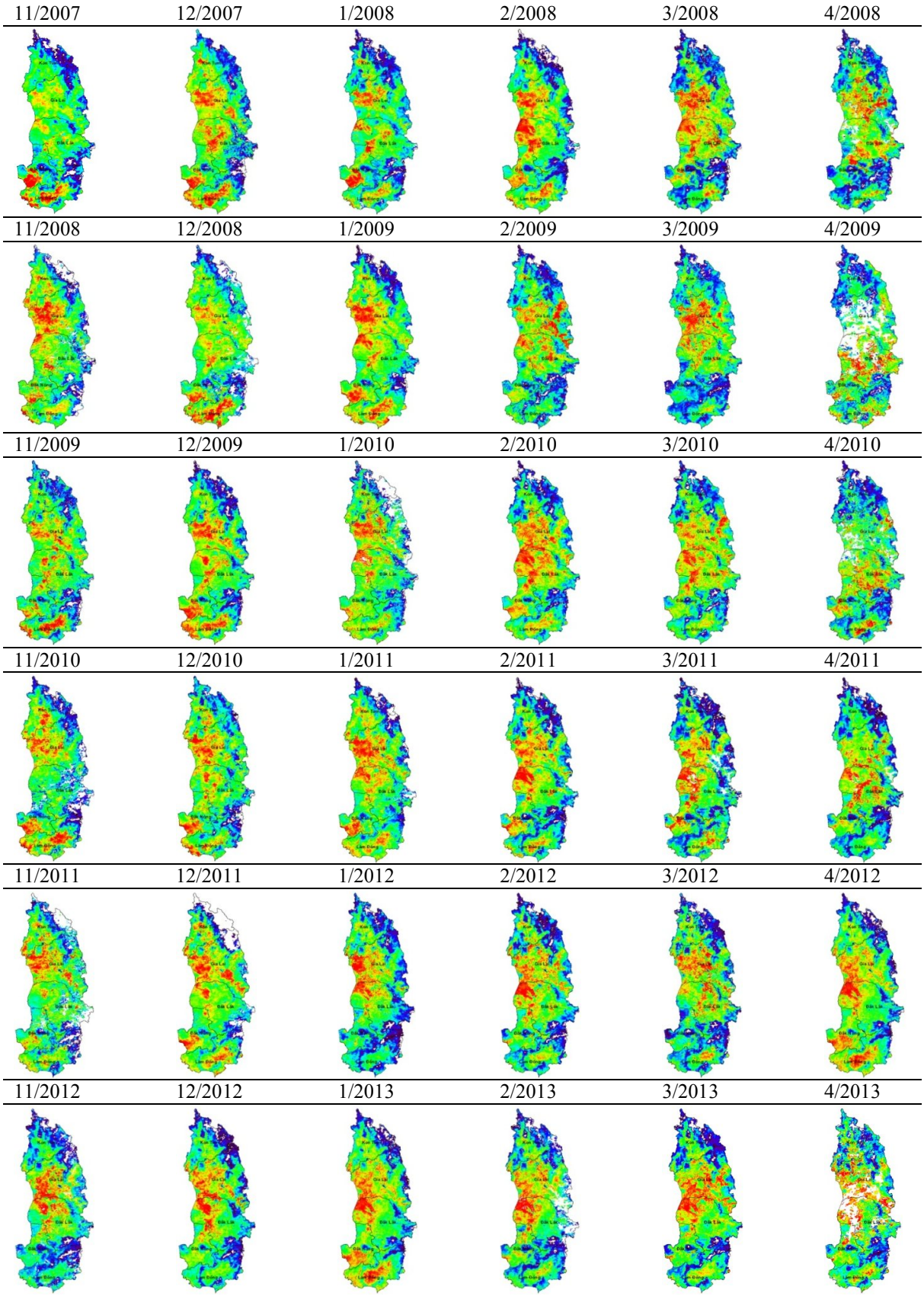

Figure 3. Time- serie TVDI maps for 6 dry seasons from 2007 to 2013

Outcome are TVDI time-series maps for Highland, white area is cloud covered region, and the redder area is, the higher drought index is (figure 3). The figure shows that the West of Gia lai and North west of Dak Lak province have the highest TVDI values. Central of Lam Dong province is "wetter", although is still red on map. Area having low TVDI values are the East of Kon Tum, the South of Dak lak and a part of western Lam Dong as well. In the end of dry season, area with high drought index tends to spread to the south. In compared with forest cover map built by FIPI in 2010 (figure 5), we can see this result is quite reasonable. Region having high TVDI value is agricultural land whereas forest has lower drought index. In addition, the North of Dak Nong province showed the high value of TVDI although this region is covered by forest. The reason is Yok Don National Park is deciduous forest, therefore in dry period, TVDI is still high due to the low NDVI value. More than that, because of the difference between Eastern and Western slopes, caused by Foehn wind effect. As a result, January, February and March are the three driest months. This time, the North East monsoon brings moisture cross ocean to the mainland, but when reaching Highland, all the rain falls down in South Central Coast and the eastern slope of Truong Son mountain before, so in dry season, Highland, which situated in western slope of Truong Son has less rain, cause more serve drought.

For verification, TVDI values were compared with average monthly rainfall data which were obtained from meteorological stations in study area from 2011 to 2012. In the beginning of the year, from January to April (the end of dry season), the inverse relationship between TVDI and precipitation is expressed quite clearly (figure 4), similar to period from October to December. In July and August, although there is more precipitation, but drought index is still high, because of high LST, high potential evaporation and low air humidity, leads to very low soil moisture. Some months don't have TVDI value because the cloud cover ratio is too high, it's impossible to achieve precise drought index.

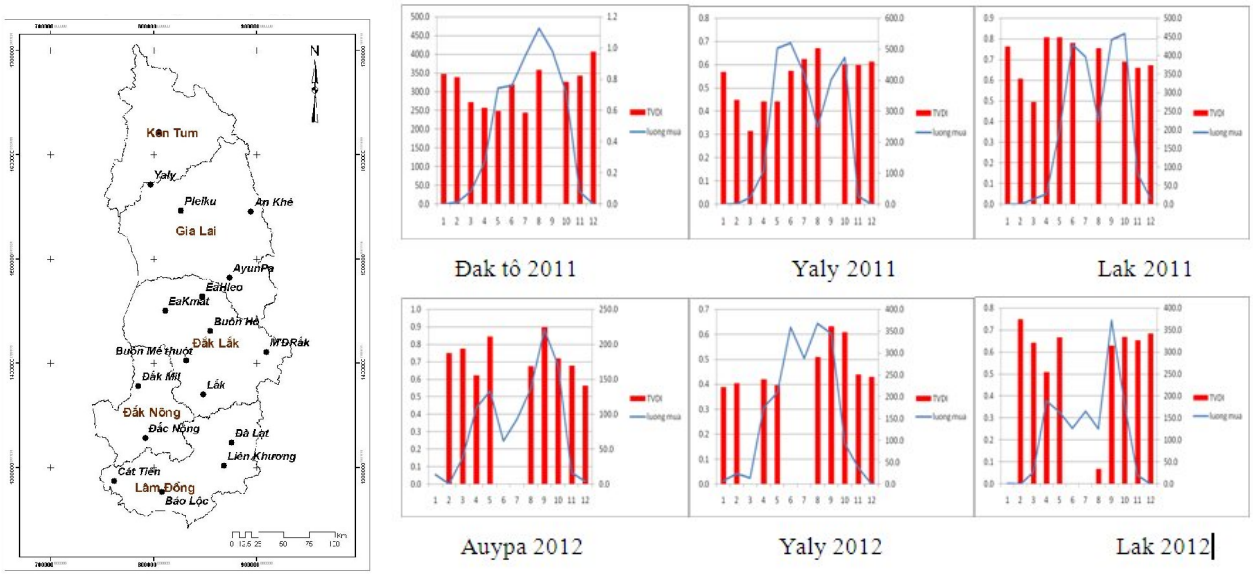

Figure 4. Location map of meteorological stations in Highland and relationship between average rainfall data in meteorological stations and TVDI values

In compared with the actual drought situation in the region, TVDI maps showed pertinent results. In fact, Gia Lai and Dak Lak are often two "hot spots", and Bao Loc district, Lam Dong province is the new one. Statistics from the meteorological stations showed that in 2013, area having water shortage was very large, except the central part of Dak Lak, the South and Southeast of Gia Lai and the East and Southeast of Lam Dong province. Region which is not so dry is just 15-20% the total area of Highland. Especially, the North of Highland including entire Kon Tum province, majority of Gia Lai province, the North and North West of Dak Lak province get serious drought [14] As of early March 2013, according to reports from the Department of Agriculture and Rural Development of Gia Lai province, more than 5,000 ha of coffee lacked of water due to depletion of water resources. The total agricultural area in the Eastern districts of this province which is affected in crop 2012 was about 4.800ha. In Dak Lak, there was 4.680ha of plant affected by drought with 486ha losting. Approximate 5,000 households in Krong Bong, Krong Ana and Krong Pak districts in this province lacked drinking water. Water shortage phenomenon occurs mainly in coffee growing land and region having very low rainfall as Krông Năng, Krông Pắk, Cư M'gar, Cư Kuin and Buôn Hồ district.

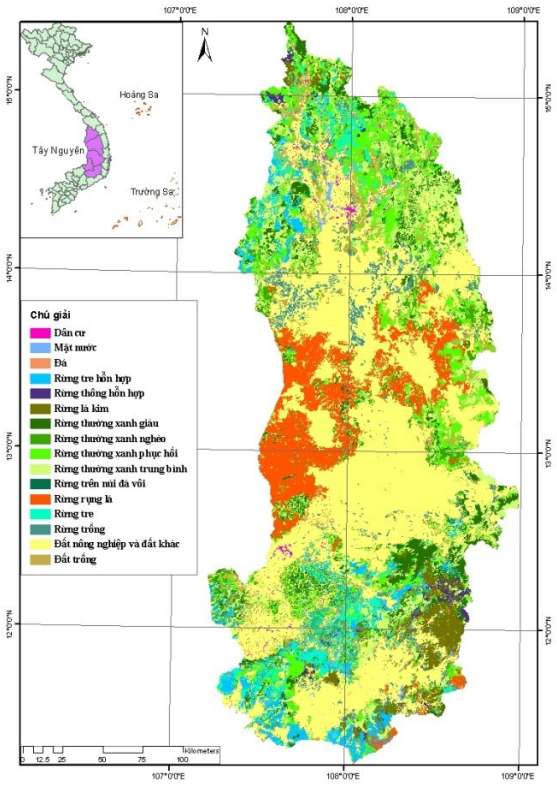

Figure 5. Forest cover map in Central Highland, 2010 (source: FIPI)

Discussion and conclusions

These findings suggest that method using MODIS to research drought is feasible. With high temporal resolution, large coverage, medium spatial resolution and free provided, MODIS images has proved strengths in environmental research in general and in drought monitoring in particular for large area like Central Highland. TVDI is calculated basing on the difference between the LST at the given pixel with the lowest LST for each range of NDVI values. The results pointed out this is potential drought indicator, it can be calculated easily and rapidly. In Central Highland, the western part of Gia Lai province and the North west of Dak Lak province have much higher drought index than other area. And this finding matches with drought situation in recent years. And the area having high TVDI value isn't confined to areas showing high LST, which can be seen close relationship with vegetation cover. In addition, the inverse correlation between drought index and rainfall data is also presented, quite clearly in the dry season. The accumulated database in many years for TVDI is necessary for climate cycles monitoring, as a basic for trend prediction of drought, and drought warning (area having high TVDI value for a long time will have higher probability to get drought than the other). Besides, the results from TVDI model will be an important data for reforestation, forest protection, land use planning, sustainable natural resources using in the local scale, and contribute to the planning, strategic economic development, natural resources protecting of government as well.

Nevertheless, the accuracy of TVDI is affected by cloud cover ratio. In the area covered almost by cloud, inverse relationship between NDVI and LST will be very vague and undoubted. Besides, TVDI is very sensitive to rainfall, just after a heavy rain, when the value of LST drops suddenly, the accuracy of TVDI is also affected markerly. Consequently, the verification TVDI model is indispensible, such as comparing relationship between LST and NDVI with simulation soil moisture models. In conclusion, TVDI is an useful indicator, can be applied in hydrological studies, and will be an accurate indicator for soil moisture. However, the relationship between TVDI and land cover should be studied further.

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