REMOTE SENSING AND GIS OF AGRICULTURAL DROUGHT MONITORING IN THE NORTH CENTRAL REGION, VIETNAM

Nguyen Thi Thu Thuy
thuy.ntt@tnus.edu.vn

Nguyen Thi Bich Hanh
hanhntb@tnus.edu.vn
Faculty of Environmental Sciences and Earth, Thai Nguyen University of Scienses, Thai Nguyen, Vietnam

Abstract

Agricultural drought is a natural hazard that characterized by shortage of water supply. In recent decades, the scientists usually deal with phrases Agricultural drought monitoring as an essential component of drought risk management and using remote sensing (RS) and Geography Information System (GIS) based on drought indicators, proposed and widely used in the field of drought monitoring. This paper presents some agricultural drought indicators to generate a suite of drought levels at monthly, seasonal, and annual time scales for the North Central regions, Vietnam. MODIS satellite image data and threshold drought lever were classified according to the measurement data survey that regarding the law of drought in Vietnam. Based on calculating NDVI index, our research built maps of VCI, LSWI, VTCI indicators. All the data sets are being produced and updated in near-real time to provide information about the onset, progression, extent, and intensity of drought conditions at research region.

Keywords: Agricultural drought, indicators, MODIS satelite image, North Central Region.

1. Introduction

Drought is not only one of common disasters in Vietnam, ranking third place in disasters, only after flood and storm, but also experienced the longest and strongest El Niño-induced drought and saline water intrusion. According to the collected statistics, during the past 50 years, droughts have taken place in 40 years in different extents and locations. Drought also affected more than 18 provinces in the three regions which produce key agricultural export and food security crops such as rice, coffee, pepper, fruits and aquaculture. Particular vulnerable groups such as the poor, women headed households, landless, people with disabilities, children and the elderly are more heavily impacted than others. [4]

According to the Vietnam national hydro-meteorological service, in the last 50 years, Vietnam has more than 38 years that appearing drought (make up 76%) with difference drought level and drought regions, affecting seriously the development of economic - society. Vietnam ranked 13/16 of top leading country suffered a strong impact of the phenomenon of global climate change in the next 30 years (Verisk Maplecroft 10/2010) . In the context of current climate change, Vietnam will be forecasted to have a heavy impact of rising sea levels, increasing temperatures and changing seasonal climate regime increasingly deeper. This means that with the increase of drought (both in frequency and quantity) in the next decade.

As regard the drought in the North central region, it not only seemly occur on whole area, but also appears during both winter-spring and summer- autumn crop seasons.

Typically drought occurred on the large regions, if using the traditional methods to assess its serve weather condition, it will be very difficult. Therefore, database from Earth observation satellite (EOS) was very helpful and deserve attention in this condition. NOAA and MODIS data can suply lots of informations about The Earth surface through difference spectral bands as spectrum band, near infrared and thermal infrared. NDVI index combines informations in red spectral bands and near-infrared bands have been used effectively in health status monitoring vegetation cover. Along to the development and increasingly modern remote sensing technology whole the world has been the application of remote sensing to monitor and forecast drought and yielded practical results.

2. Methods

Drought indices are quantitative measures that characterize drought levels by assimilating data from one or several variables indicators such as precipitation and evapotranspiration into a single numerical value. Such an index is more readily useable than raw indicator data. The nature of drought indices reflects different events and conditions; they can reflect the climate dryness anomalies (mainly based on precipitation) or correspond to delayed agricultural and hydrological impacts such as soil moisture loss or lowered reservoir levels.

In addition, this research focus on some of these models allow this below:

Method of the relationship between vegetation indices: this method almost use specific reflex of crops and land surface at wavelength near-infrared spectrum to determine the soil moisture

Method of infrared heat: This method uses thermal emission reflex of the surface on the basis of the thermal inertia and lack of land surface water index to assess drought of cover land.

The method of using high frequency communication and sensing

3. Results

3.1. Overview of Agricultural Drought in the North Central Region

During the summer monsoon here have many hot dry west winds are harsh as Dong Ha, Tuong Duong. The strong development of hot weather would falsify evolution-humid rainy season in the North Central considering the general situation of the Northern climate area.

The degree of hot dry here tied to the mechanism of the southwest monsoon. Laos wind is very dry and hot. July is the most popular month of the southwest with the highest temperature may be over 42^oC. In this area, the rainfall from the first season up to June and July not only did not increase as a general rule, but also it is reduced, creating a local phenomenon characteristic term. Rain season began to increase from August and reached its maximum in September or October with 3-4 times the rainfall in other months.

In crop seasons during of last years, drought event has affected from 12,000 to 50,000 hectares and totally lost from 1,000 to 13,000 hectares of agricultural land.

3.2. Evaluating the Relationship between Vegetation Indicators

3.2.1. Normalized Difference Vegetation Index (NDVI)

The NDVI algorithm subtracts the red reflectance values from the near-infrared and divides it by the sum of near-infrared and red bands.

$$NDVI = \frac{NIR-RED}{NIR+RED} \quad (3.1)$$

This formula allows us to cope with the fact that two identical patches of vegetation could have different values if one were, for example in bright sunshine, and another under a cloudy sky. The bright pixels would all have larger values, therefore having a larger absolute difference between these bands. It is avoided by the sum of the reflectance.

Theoretically, NDVI values are represented as a ratio ranging in value from -1 to 1 but in practice extreme negative values represent water, values around zero represent bare soil and values over 6 represent dense green vegetation.

3.2.2. Vegetation Condition Index (VCI)

The Vegetation Condition Index (VCI) compares the current NDVI to the range of values observed in the same period in previous years. The VCI is expressed in % and gives an idea where the observed value is situated between the extreme values (minimum and maximum) in the previous years. Lower and higher values indicate bad and good vegetation state conditions, respectively.[3]

$$\left[VCI = \frac{(NDVI_j - NDVI_{\min})*100}{(NDVI_{\max} - NVDI_{\min})} \right] \quad (3.2)$$

3.2.3. Land Surface Water Index (LSWI)

For more than 20 years the Normalized Difference Vegetation Index (NDVI) has been widely used to monitor vegetation stress. It takes advantage of the differential reflection of green vegetation in the visible and near-infrared (NIR) portions of the spectrum and provides information on the vegetation condition. The Land Surface Water Index (LSWI) uses the shortwave infrared (SWIR) and the NIR regions of the electromagnetic spectrum. There is strong light absorption by liquid water in the SWIR, and the LSWI is known to be sensitive to the total amount of liquid water in vegetation and its soil background. In this study we investigated the LSWI characteristics relative to conventional NDVI-based drought assessment, particularly in the early crop season.

LSWI index was caculated by below formula (Hunt et al., 1987&1989)

$$LSWI = \frac{\rho_{NIR} - \rho_{SWIR(2130nm)}}{\rho_{NIR} + \rho_{SWIR(2130nm)}} \quad (3.3)$$

3.2.4. Vegetation - Temperature Dryness Index VTCI

VTCI is lower for drought and higher for wet conditions. The value of VTCI ranges from 0 to 1; the lower the value of VTCI, the higher is the occurrence of drought. [5]

Mathematically it can be written as

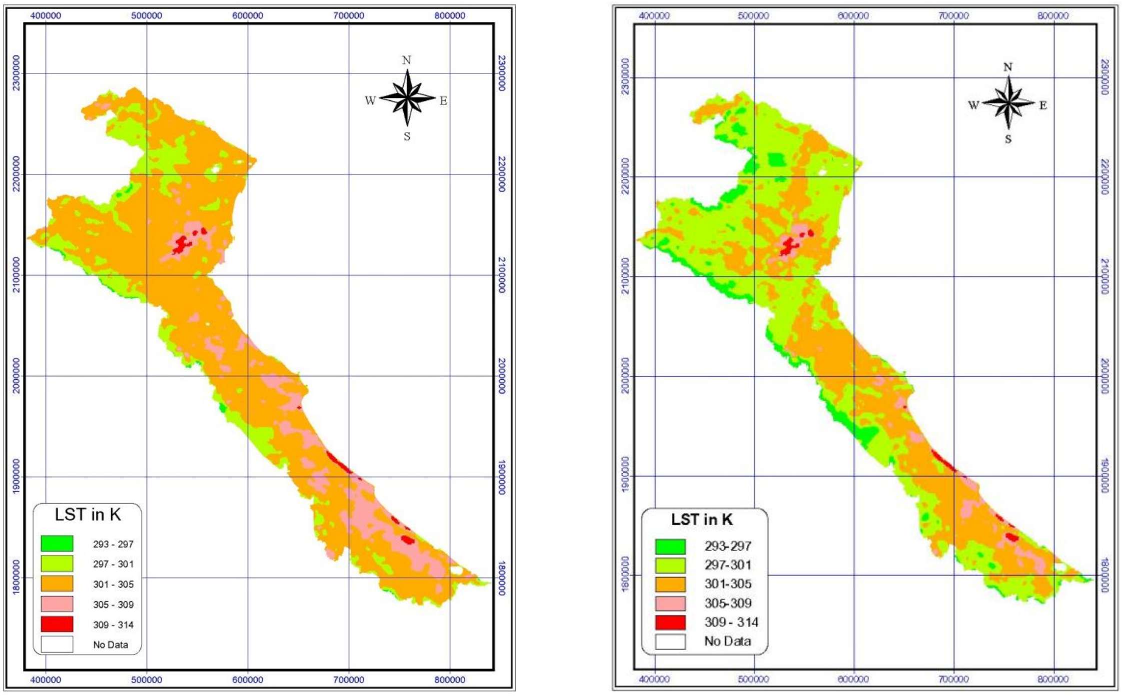
$$VTCI = \frac{LST_{NDVIimax} - LST_{NDVIi}}{LST_{NDVIimax} - LST_{NDVIimin}} \quad (3.4)$$

3.3. Satellite Data

Satellite data includes MODIS image 8-days and 32-days from 2000 year to 2013. These data are at 1B type. Satellite data used for study are MODIS Land surface temperature and surface reflectance and the product name is MOD11A2 and MOD09A1 respectively. These two products have been downloaded from EOS data gate way for the period of November to May from 2000 to 2013.

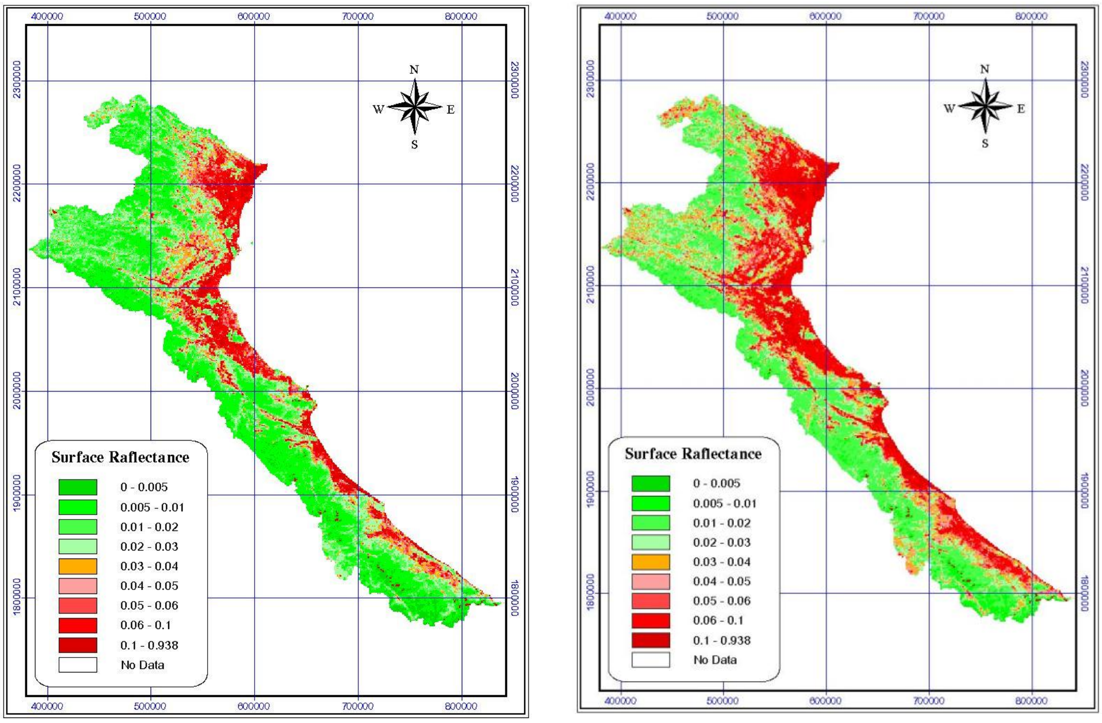
The MOD11A2 data are provided every 8 days as a gridded level - 3 product in the Sinusoidal projection. It has twelve layers and out of these only layer 1 - MODIS_LST_Day_1km and layer 02- MODIS_QC_Day has been used for analysis. Land surface temperature image was retrieved from MODIS data during 6th April 2012 and 6th April 2013 over the North Central region. It is an example of the MODIS level 3 LST 8 - Day product at 1 km resolution. MOD11A2 is a composited version of the Level 3 daily LST product.

MOD09A1 provides bands 1- 7 at 500 meter resolution in an 8- day gridded level - 3 product in the Sinusoidal projection. Each MOD09A1 pixel contains the best possible L2G observation during an 8 - day period as selected by high - observation coverage, low - view angle, the absence of clouds or cloud shadow, and aerosol loading. Science Data sets provided for this product include reflectance values for Bands 1 - 7, quality assessment, and the day of the year for the pixel along with solar, view, and zenith angles. The surface reflectance (MOD09A1) and NDVI derived from surface reflectance image shown in below figure was retrieved from MODIS data during 27th December 2012 and 27th December 2013. It is an example of the MODIS level 3 surface reflectance product at 500m resolution.



Land Surface Temperature during 6th April 2012 Land Surface Temperature during 6th April 2013

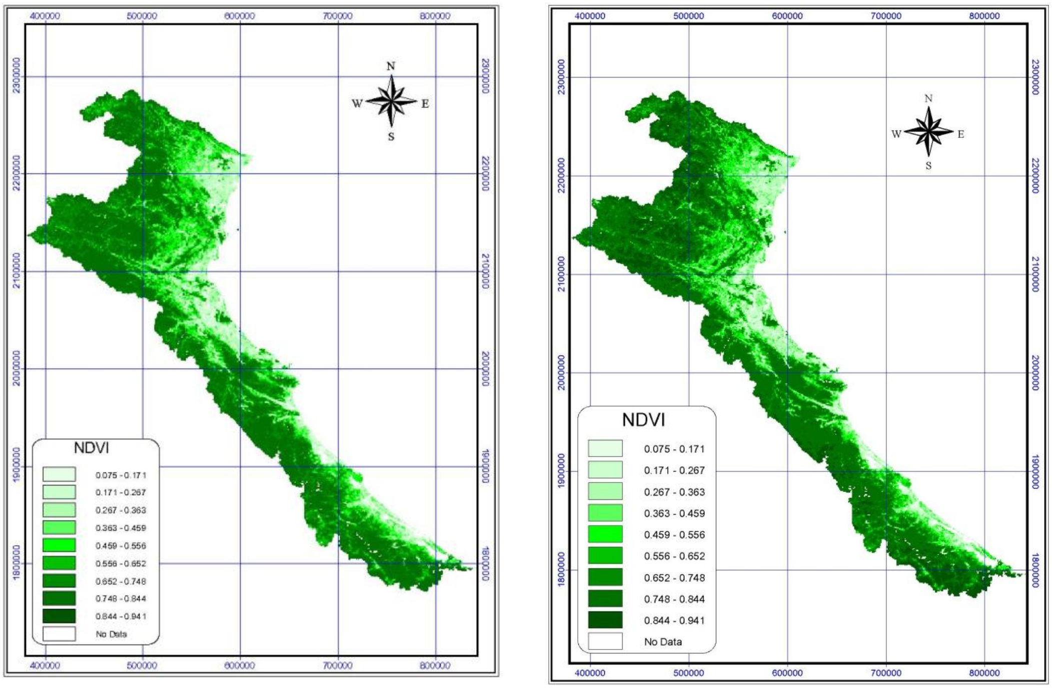
Figure 1. The Land Surface Temperature in different years



Surface reflectance during 27th December 2012 Surface reflectance during 27th December 2013

Figur 2. Surface reflectance in North Central region

It is a measure of the amount and vigour of vegetation at the surface. The magnitude of NDVI is related to the leve l of photosynthetic activityin the observed vegetation. In general, higher values of NDVI indicate greater vigour and amounts of vegetation. The reason NDVI is related to vegetation is that healthy vegetation reflects very well in the near infrared part of the spectrum. Previous research suggests the estimation of air temperature extrapolating the best fit line through the NDVI of full vegatation canopy and LST correlation.



NDVI during 27th December 2012 NDVI during 27th December 2013

Figure 3. Normalized difference vegetation index in North Central region

3.4. Results of Drought Assessment by Satellite Imagines

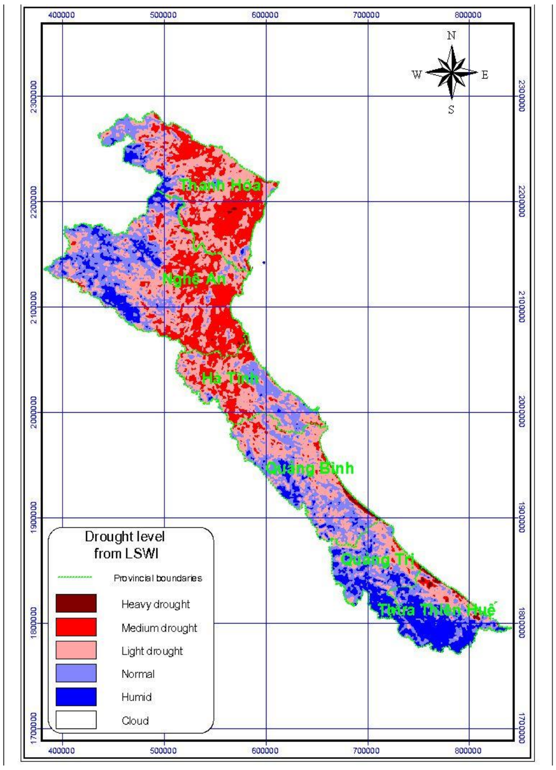
3.4.1. Results by Calculating Land Surface Water Index

Land surface water index was calculated from May, 2012 to May 2013 by ENVI software base on (3.3) equation. The index is calculated from LSWI remote sensing images and after that it will be compared with field measurements to determine drought risk following levels: heavy drought, moderately drought, light drought, normal, humid, cloud.

Figure 4a and 4b indicated that LSWI index results to representing two-week dry season of 2012 and 2013, results show that the distribution of LSWI relatively consistent with the distribution of arid regions. The North Central Region is always to be on a stress drought. In the last months of 2012 year and the first months of 2013 year, LSWI values is almost low, expressed drought appears over the wide area.

North Central region also has a large beaches with predominantly white sand, so not only in the winter but also in the summer LSWI values is very low.

From the above analysis it can be concluded that the distribution of LSWI values is consistent with the law of drought evolution in the region. So LSWI calculated by remote sensing can be used as an indicator in the assessment and monitoring drought in the North Central region.



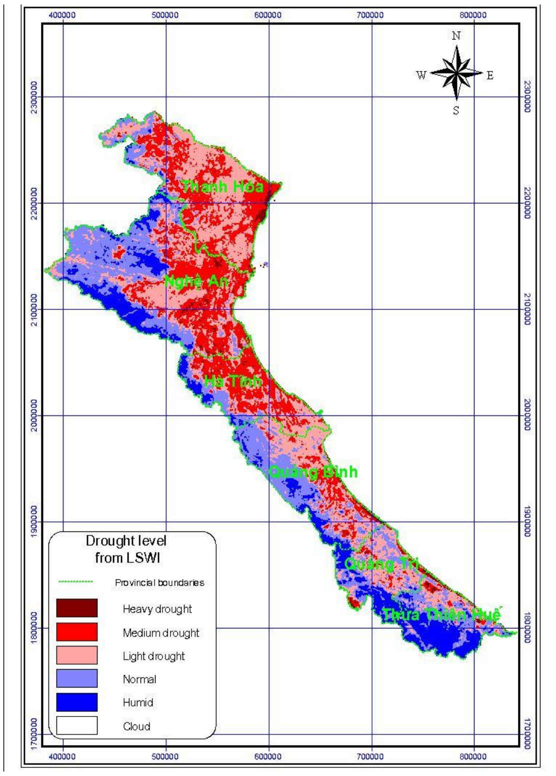


Figure 4a. LSWI index 4th week November 2012

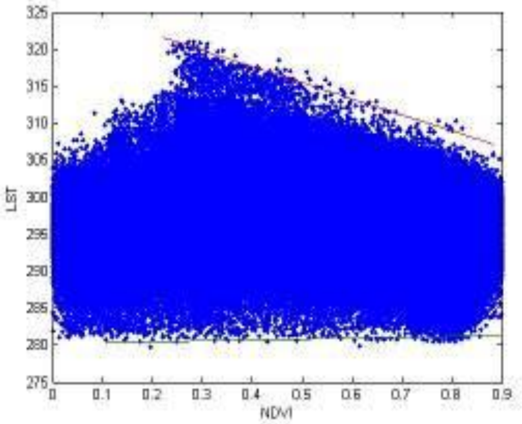
Figure 4b. LSWI index 3th week February 2013

3.4.2. Result of Drought Index from Caculation VTCI Value

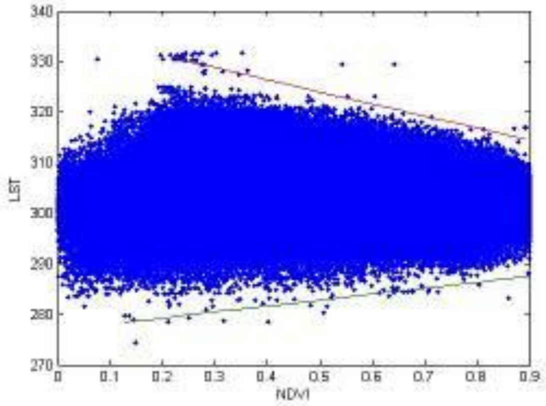
VTCI has been computed based on the NDVI-Ts space, 2D scatter plot relation for each pixel. The warm edge and cold edge pexels are subjected to linear regression equation and the derived equations are used for computation of VTCI using band math in ENVI, where land surface temperature (LST) and NDVI images are used as an input parameter for VTCI equations. VTCI has been computed for 13 years (2000 - 2013), which comprises Julian day of 241 to 297. This index was calculated for September and October month in each year for regional agricultural drought monitoring because these two months corresponds to reproductive period which is more sensitive to thermal stress. Hence this index could better represent the drought during reproductive phase. VTCI is more sensitive towards the reproductive stage of the crops in lieu of early stage of the crops, this is due to land surface is more sensitive towards the dryness rather than more moisture content in the soil as well as there is an inverse relationships existing between LST and NDVI.

Base on the indexes of LST, NDVI database and their relationship, my research caculated and gave results about the scatterplots of LST and NDVI for weeks in the North Central region.

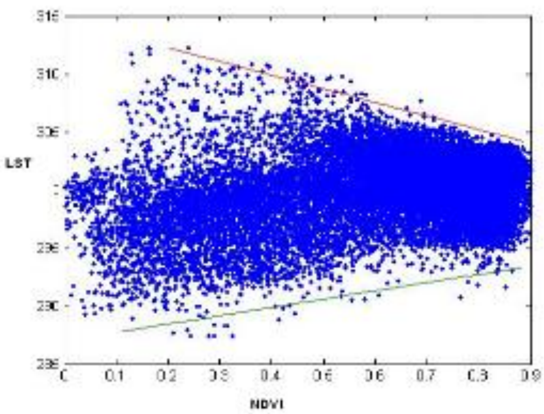
The scatterplots of LST as a function of NDVI index that was built for each of MODIS images combination in the dry season. Calculating results was expressed at the figure 5 below:



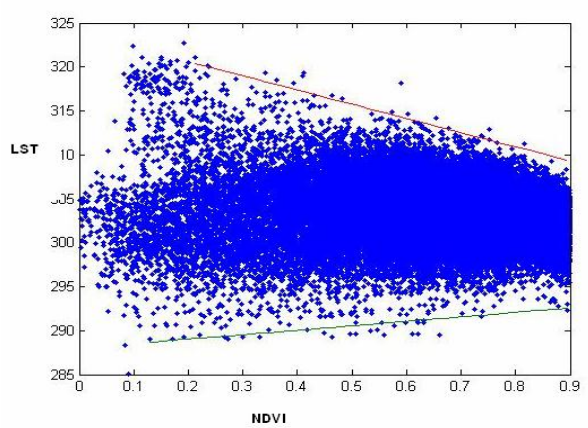
3th week of November 2012



the 2nd week of February 2013



3th week of December 2012



2nd week of March 2013

Figure 5. Dispersion graph of LST and NDVI in the North Central region

VTCI index is caculated by (3.4) formula, the value of $LST_{NDVIi\max}$ and $LST_{NDVIi\min}$ indexes are defined as the surface's average temperature on condition that water is supplied with limited or unlimited. Dry edges (red line) and wet edges (blue line) was determined by linear regression analysis.

From the linear regression model in the figure 5 show that: the correlation coefficient of the "dry edge"'s equations very high (R> 0.8), the correlation coefficient of "wet edge" equations although not as high as dry edge, but the trend is also consistently with the evaporation process. In the other hand, the change of LST value in the wet edges is smaller than the major change of NDVI index, so that, using the equations of wet edges in caculate dry lever that impact to the results but not very strong. The slope of the dry edge is usually bigger than wet edge lines, its demonstrating that the influence of the LST-NDVI into drought process is bigger than into wet process, consistent with the reality of the drought process.

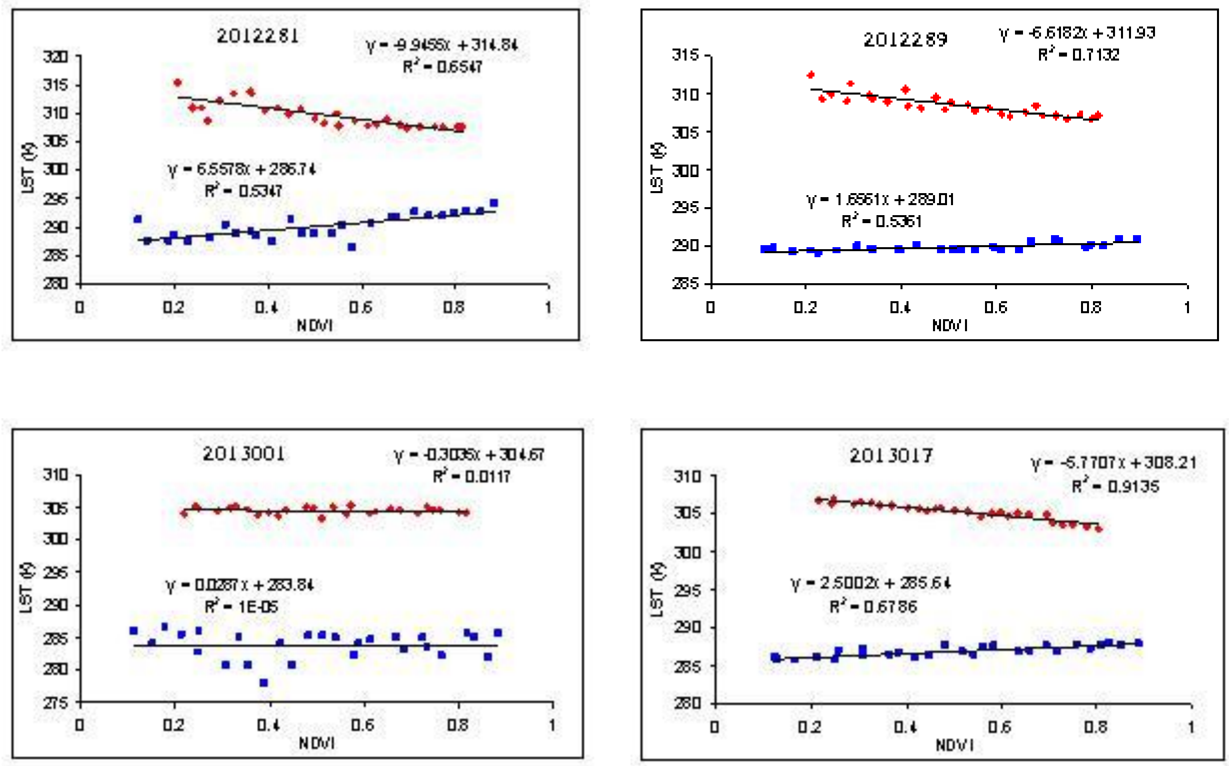


Figure 6. Graph of wet edges and dry edges in the North Central region (2012 – 2013)

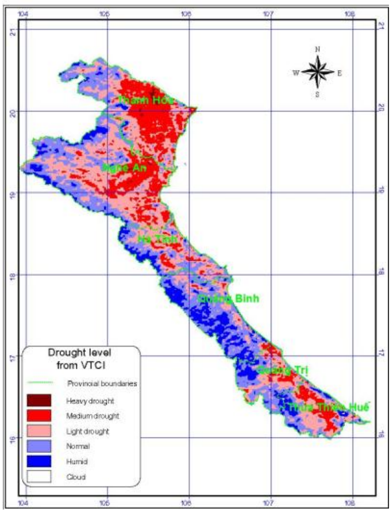
This paper used to MODIS data to calculated NDVI and LST indexes, and then caculated VTCI index for each week for the phase appeared arid and hot from May, 2012 to May, 2013. Figure 6 shows that the spatial distribution of the VTCI index in the North Central region. Color palette represents the level of drought, VTCI value ranges from 0 to 1, the smaller the value VTCI (red gray area) represents arid areas and the greater VTCI (blue zone) shows adequate water supply area.

From figure 6 also shows that the low of VTCI index usually appear in the coastal the North Central region, the deeper going into the mainland, the higher of VTCI index.

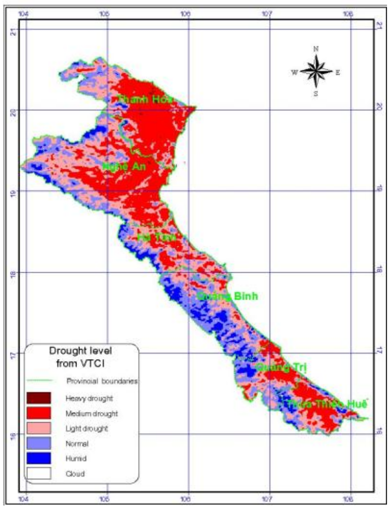
Temperature of February is higer than temperature in last December in the North Central region, mainly cause in these months it almost no rainfall, evaporation process was strong, the remaining water was reserved in soil fades lead to widespread drought in the summer.

To compare the value between LSWI and VTCI indices in the same week show that: the distribution of both indices is quite appropriate term, almost the entire province of Thanh Hoa, Nghe An are located in area have the range heavy drought and medium drought, provinces of Ha Tinh, Quang Tri, Hue have lighter limited extent, but the large of the area is also located in the medium drought and lightly drought.

The results of drought indices were caculated through VTCI and LWSI indicators is the same in the same week and the same area), but the result of calculating VTCI index usually right in the dry months within the area that has a fairly homogeneous of climate conditions.



Hình 7.a. VTCI index of 4th week of November 2012



Hình 7.b. VTCI index of 3rd week of February 2013

4. Discussion and Conclusion

Drought has become a serious challenge in the world in general and Vietnam in particular. Tracking, monitoring and forecasting drought is an urgent problem.

Along with the surface observation data, the integration information of remote sensing with different spatial resolution and time, using drought indicators suitable for each region, each season is fully capable to serve the surveillance and monitoring of drought in our country.

LSWI index calculated on the MODIS satellite image data and threshold drought lever were classified according to the measurement data survey practice is consistent with the law of drought events in Vietnam in general and research area in particular. Therefore LSWI index base on remote sensing can be used as an indicator in the assessment and monitoring of drought in the North Central region.

The use of VTCI indicators based on the correlation term NDVI-LST, proven by the results of calculations drought value from meteorological stations as appropriate in dry season and in relatively homogeneous regions of climatic conditions. So this is also an indicator of drought assessment by remote sensing data in North Central region.

5. References

1. Nguyễn Trọng Hiệu (1995). Phân bố hạn hán và tác động của chúng ở Việt Nam, Đề tài NCKH cấp Tổng cục (1995).

2. Trịnh Quang Hoà (2001). Các yếu tố gây hạn hán, phân loại và phân cấp hạn hán, Báo cáo khoa học Đề tài nhánh thuộc đề tài HMC (2001).

3. Ali Akbar Damavandi, Mohammad Rahimi, Mohammad Reza Yazdani, Ali Akbar Noroozi, (2016), Assessment of Drought Severity Using Vegetation Temperature Condition Index (VTC) and Terra/MODIS Satellite Data, Journal of Rangeland Science, 2016, Vol. 6, No. 1

4.UNDP Viet Nam (2016), Vietnam drought and saltwater intrusion transitioning from Emergency to Recovery, Analysis Report and Policy Implications.

5. https://land.copernicus.eu/global/products/vci