# USING MODIS SATELLITE IMAGE TO OBSERVE LONG TERM DROUGHT


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**KEY WORDS:** MODIS, Soil moisture, Drought, TVDI, NMDI



**ABSTRACT:** Soil moisture is an important factor for the exchange of water between the land surface and plant transpiration. It has tremendous effects on agriculture, the environment, the ecological system, weather and climate. It is hard to evaluate the long term land surface dryness by field investigations or a ground survey alone. It has been shown in the literature that using Moderate Resolution Imaging Spectroradiometer (MODIS) satellite images to observe the land surface water content is feasible. A simple land surface dryness index (Temperature – Vegetation Dryness Index, TVDI) can be calculated based on an empirical parameterization of the relationship between the Land Surface Temperature (LST) and the Normalized Difference Vegetation Index (NDVI). In general, the LST and NDVI can be obtained from MODIS products. Another index for monitoring the water condition of the land surface is the Normalized Multi-Band Drought Index (NMDI). Basically, the reflectance difference between two liquid water absorption channels in the short wave infrared (SWIR) is used to describe the moisture content with the near infrared (NIR) channel as the reference. In this study, by using satellite data on the dry season climate as a study case, the comparison of drought sensitivity between the TVDI and NMDI indices is carried out. The preliminary results archived by visual comparisons between TVDI and NMDI indicated that between the two datasets.


## 1. INTRODUCTION

A drought can cause many problems, like ecosystem imbalance, shortages of grain and an increase in suspended particles. Water scarcity area monitoring is necessary to prevent serious droughts from happening. Soil moisture is an important parameter during a drought event, because it is related to the water cycle and global energy (Engman, 1991). One method of detecting soil moisture is to use a microwave instrument in remote sensing, but the temporal resolution has limitations. Another method to evaluate the water content indirectly is by using radiometric measurements in the visible, near infrared and thermal infrared. Many studies suggest that a combination of the land surface temperature (LST) and the normalized difference vegetation index (NDVI) can provide an estimate of the surface soil moisture. Sandholt et al. (2002) suggested a land surface dryness index called the temperature-vegetation dryness index (TVDI), which is based on NDVI and the surface temperature. The other method for estimating the soil moisture is to use radiometric measurements in the visible, near infrared and short wave infrared. Wang and Qu (2007) proposed that the Normalized Multi-band Drought Index (NMDI), which is based on a property from two liquid water absorption bands in the short wave infrared, has a different sensitivity to soil and vegetation. The main objective of this study is to evaluate the performance of TVDI and NMDI for soil moisture monitoring in Nicaragua during the dry season using MODIS data. This study focuses on the performance which TVDI and NMDI used to monitor soil moisture. Test area in Nicaragua, on the dry season.

## 2. METHODOLOGY

### 2.1 Temperature–Vegetation Dryness Index, TVDI

Sandholt et al. (2002) proposed the TVDI method to describe the relationships among the LST, NDVI and soil moisture. The TVDI method is based on the energy exchange in the land surface thermal radiation, vegetative cover and soil moisture evaporation. Varying degrees of NDVI in the NDVI-LST space have a maximum and a minimum temperature in relation to low and high soil moisture, which takes into consideration dry and wet surface conditions. The maximum and minimum temperatures vary continuously as the NDVI changes. In $T_s$-NDVI space, the different soil moisture contents can be characterized with the upper boundary and lower boundary also called the dry edge and wet edge. TVDI can be calculated for each pixel from $T_s$-NDVI space using the following form, TVDI can be defined as

$$\mathrm{TVDI} = \frac{T_s - T_{s_{min}}}{T_{s_{max}} - T_{s_{min}}}, \tag{1}$$

where $T_s$ indicates the surface temperature, $T_{s_{max}}$ and $T_{s_{min}}$ represent the maximum and minimum surface temperature given the same NDVI value. Figure 1 shows the relationships among $T_s$, $T_{s_{max}}$ and $T_{s_{min}}$.

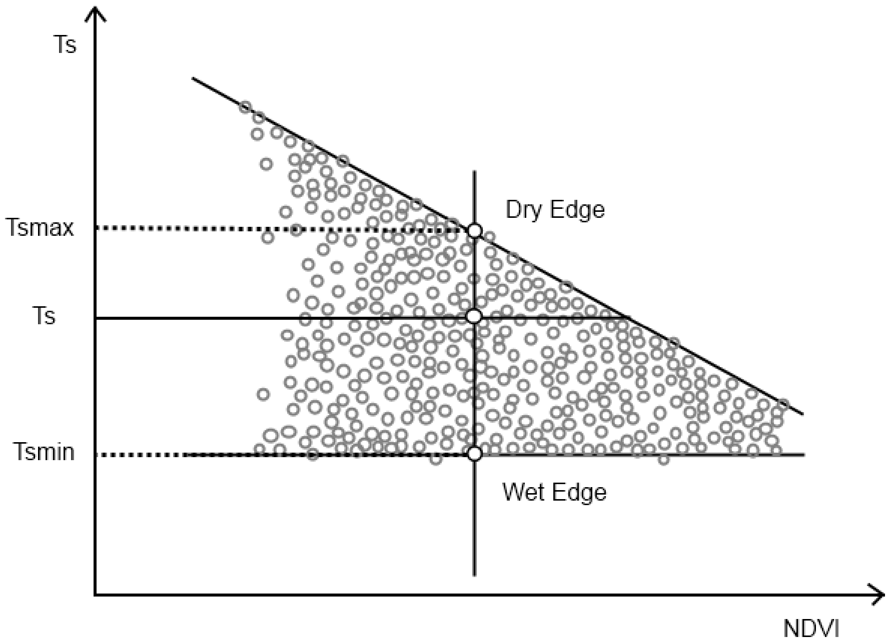


Figure 1. The relationships among $T_s$, $T_{s_{max}}$ and $T_{s_{min}}$

**2.2 Normalized Multi-band Drought Index, NMDI**

Wang and Qu (2007) proposed the NMDI method to assess surface moisture by using multiple band information. When a satellite obtains the surface reflectance, the results consist of the soil moisture and vegetation water content. The NMDI method is based on a multi-band calculation, using the difference between two liquid water absorption bands in SWIR as soil and vegetation sensitive bands to separate the mixed surface reflectance results. The conception behind the NMDI is that the soil and vegetation show a different reaction as the water content increases or decreases, and this will show a response in the NMDI value. Each pixel has to be defined as vegetation cover or bare soil, and then the NMDI can be calculated. A vegetation pixel's NMDI is defined as

$$\mathrm{NMDI}_{veg} = \frac{R_{0.86\mu m} - (R_{1.64\mu m} - R_{2.13\mu m})}{R_{0.86\mu m} + (R_{1.64\mu m} - R_{2.13\mu m})}. \tag{2}$$

A soil pixel's NMDI is defined as

$$\mathrm{NMDI}_{soil} = 0.9 - \frac{R_{0.86\mu m} - (R_{1.64\mu m} - R_{2.13\mu m})}{R_{0.86\mu m} + (R_{1.64\mu m} - R_{2.13\mu m})}, \tag{3}$$

where $R_{0.86\mu m}$, $R_{1.64\mu m}$ and $R_{2.13\mu m}$ are the surface reflectance obtained from the satellite sensor. $R_{0.86\mu m}$ is centered at the NIR region, which is insensitive to water content change. $R_{1.64\mu m}$ and $R_{2.13\mu m}$ are centered at the SWIR region, which is sensitive to water content change. $\mathrm{NMDI}_{soil}$ has to be remain consistent with $\mathrm{NMDI}_{veg}$, for typical very dry bare soil; the NMDI value range is from 0.7 to 0.9 (Wang and Qu, 2007), so to make the $\mathrm{NMDI}_{soil}$ consist with $\mathrm{NMDI}_{veg}$ of vegetation pixels, $\mathrm{NMDI}_{soil}$ need to turned direction and shifted. Figure 2 shows the flowchart of NMDI processing; Wang and Qu (2007) give a threshold to define the vegetation pixel when the NDVI is greater than 0.4.

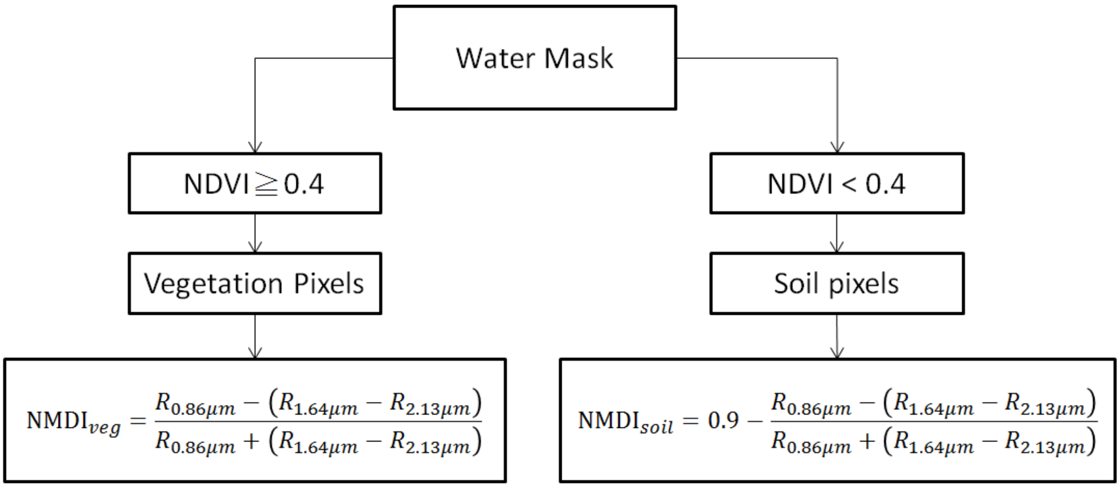


Figure 2. The flowchart for the NMDI calculation

## 3. RESULTS

Using the TVDI and NMDI methods, TVDI and NMDI maps can be created. For this purpose we pick some results in 2010, the dry season in Nicaragua. In Nicaragua, the Pacific side is drier than the Atlantic side, so we can assume that the western side will be drier than the eastern side.

We evaluate the data quality to avoid cloudy days, and then we exclude water body and regions where the LST has no data for it might be caused by the cloud affect. In these results, the TVDI and NMDI values demonstrate different directions from dry to wet. A higher TVDI value indicates drier, a higher NMDI value indicates wetter. So the blue color side means wet, the red color side means dry. We can find the soil moisture climate in Nicaragua and some relationship between the two indices. However, parts of the NMDI map look like a noise effect, compared with the original image, these noises may be from cloud shadow or the SWIR sensor.

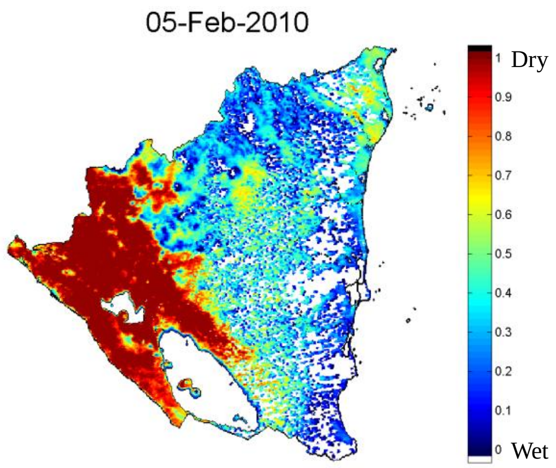


Fig 3. TVDI map

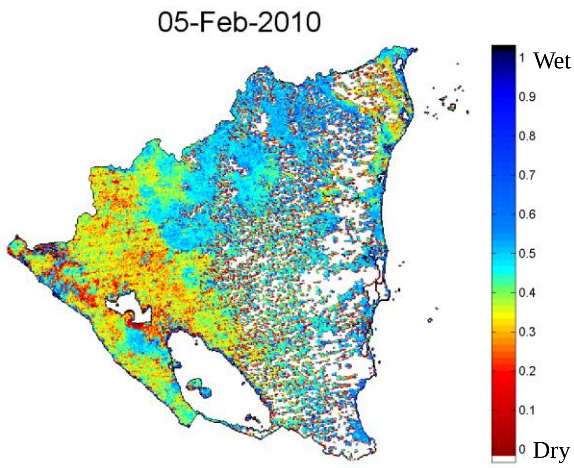


Fig 4. NMDI map

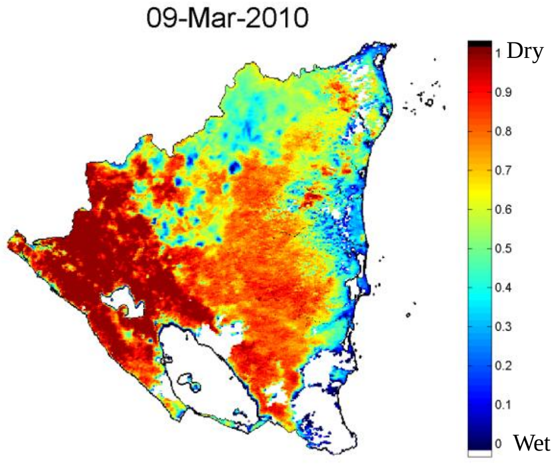


Fig 5. TVDI map

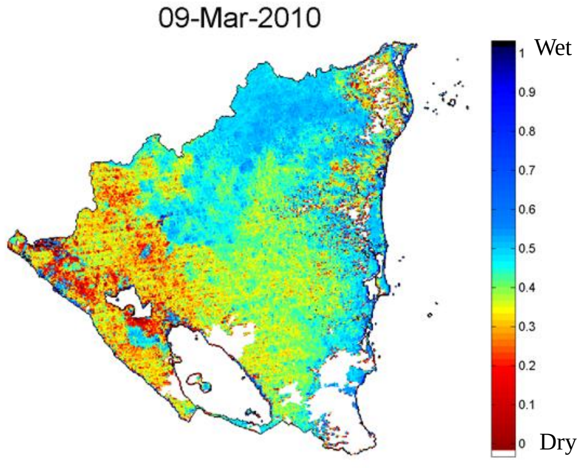


Fig 6. NMDI map

## 4. CONCLUSION

The TVDI and NMDI can be used to evaluate surface soil moisture; both have advantages and disadvantages. TVDI seems to over enhance the drier part, while the NMDI seems to lose some contrast in the drier region. The NMDI results really have some relationship with the TVDI results, because both western part drier than eastern part. But some parts of the NMDI processing can be improved. First, In Nicaragua, the western side should be dry bare soil, so the NMDI of soil equation should be discussed. Second, the definition of the soil and vegetation should be more rigorous, in which case the discussion of the NMDI property will be more persuasive. When these problems are solved, the TVDI and NMDI results can be compared with the real water content data, and the accuracy of the two indices can be calculated. In future works, we will investigate applicability of the TVDI and NMDI indices. The results will be compared with the real surface soil moisture.

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