DROUGHT MONITORING USING MODIS DATA IN CENTRAL AMERICA

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ABSTRACT

This study aimed to delineate drought-prone areas in Central America using MODIS data. The data were processed for 2014 using the simple vegetation health index (VHI) calculated based on the temperature condition index (TCI) and vegetation condition index (VCI). The results were verified with the Advanced Microwave Scanning Radiometer 2 (AMSR2) precipitation data, indicating close relationship between these two datasets with the correlation coefficient (*r*) value of 0.78. The larger area of severe drought was generally observed during January to April, however, declined during May–November, except for July–August due to the occurrence of a short dry spell. The results obtained from this study could be useful to devise strategies in order to mitigate negative effects of droughts on crop production.

KEYWORDS: Drought, MODIS, VHI, Central America

1. INTRODUCTION

Drought is recognized as one of the most frequent and costly natural disasters, causing negative effects on human societies and ecosystems. Identification of drought prone areas and drought prediction have received interests from scientists around the world because the results can help to mitigate socioeconomic costs. In Central America, the occurrence of more frequent and intense droughts due to climate change has caused profound effects on large cultivated areas and farm smallholders, leading to crop production losses and increased market prices of food in the region. Thus, there is an urgent need to investigate drought-prone areas for drought monitoring purposes and irrigation scheduling.

Drought can be monitored using remote sensing technology. Various satellite-based indices have been developed drought monitoring in the top few centimeters of soil. The vegetation health index (VHI), which is one of the most commonly used one developed based on the empirical analysis of the normalized difference vegetation index (NDVI) and land surface temperature (LST), was applied for drought monitoring in the study region. The combination of NDVI and LST data can provide more complete information on soil moisture status (Nemani *et al.*, 1993; Sandholt *et al.*, 2002; Carlson, 2007).

The objective of this study was to delineate drought-prone areas in Central America using MODIS data in 2014. The drought mapping results in form of spatiotemporal distributions of droughts could be useful for agronomic planners to devise strategies in respect to mitigating negative effects of droughts on crop production while enhancing food security for the region.

2. STUDY AREA

The study area including Guatemala, Honduras, El Salvador, and Nicaragua in Central America is selected for drought investigation (Figure 1). This region has a tropical climate with two seasons: dry season (December–April) and wet season (May–November), which is interrupted by a short dry period (July–August). In recent years, the occurrence of droughts has been more frequently, creating effects on crop production. For example, the delayed start of rains in 2014 led to rainfall deficits has caused severe droughts, putting the main cropping season (primera) under serious threats and having negative impacts on farming activities (Cheng *et al.*, 2015).

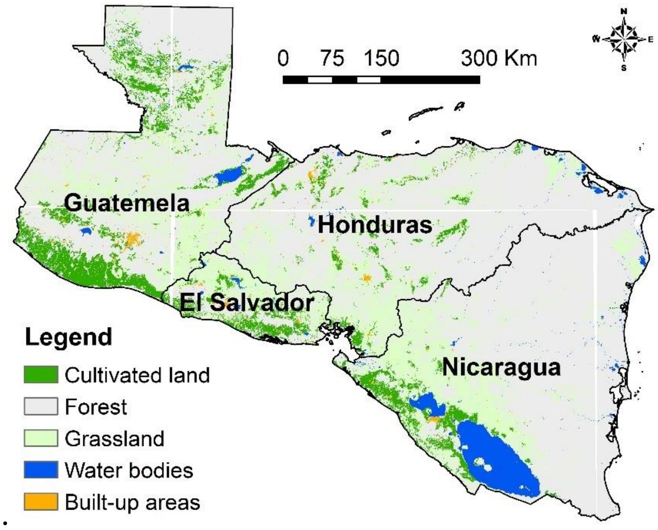

Figure 1. Map of the study region showing spatial distributions of land-use classes.

3. DATA

The monthly MODIS data (MOD13A3 and MOD11C3 products) collected from NASA for 2014 were used. The MOD13A3 product has the spatial resolution of 1 km and has been geometrically and radiometrically corrected. The MOD11C3 product derived from the MOD11C1 daily global product has 1-degree (in Kelvin) accuracy for materials with known emissivity. The accuracy of both data products have been assessed over a widely distributed set of locations and time periods via ground-truth and validation efforts. We also collected monthly AMSR2 precipitation data from JAXA to verify the drought mapping results. The data have been validated using in-situ observations and are registered using the world geodetic system (1984), providing amount of surface rainfall (mm/hr.) with a 1-km spatial resolution.

4. METHODS

The VHI used to investigate drought-prone areas in the study region was calculated using the following equation:

$$VHI = a * TCI + b * VCI, \tag{1}$$

where, TCI and VCI were calculated as:

$$TCI = \frac{LST_{\max} - LST}{LST_{\max} - LST_{\min}}, \tag{2}$$

$$VCI = \frac{EVI - EVI_{\min}}{EVI_{\max} - EVI_{\min}}, \tag{3}$$

where LST and EVI are the MODIS LST and EVI, LST_{min} and LST_{max} are the maximum and minimum LST, and EVI_{min} and EVI_{max} are the maximum and minimum EVI. In this study, an equal weight (a, b = 0.5) was assigned to both indices. The VHI values range from 0 to 1, indicating changes in vegetation conditions from extremely unfavorable (vegetation stress) to optimal (favorable) can be categorized into five classes to characterize drought levels: extreme drought (<0.1), serve drought (0.1–0.2), moderate drought (0.2–0.3), slight drought (0.3–0.4), and no drought (>0.4).

We performed the assessment of drought mapping results using the monthly AMSR2 precipitation data (10 km resolution). The VHI results (1 km resolution) were first resampled to the same resolution with the AMSR2 precipitation data. The linear regression was then used to examine the correlation between the cumulated VHI data and precipitation data.

5. RESULTS AND DISCUSSION

The VHI results verified with the accumulated AMSR2 precipitation data indicated close relationship with the precipitation observations measured from the C-band passive microwave radiometer of the AMSR2 on-board Aqua platform (Figure 4). The linear model had correlation coefficients (r) of 0.78 and F-statistics of 4,324.6 with p-value <0.001, respectively, indicating that the relationship was significant at 95% coefficient limit.

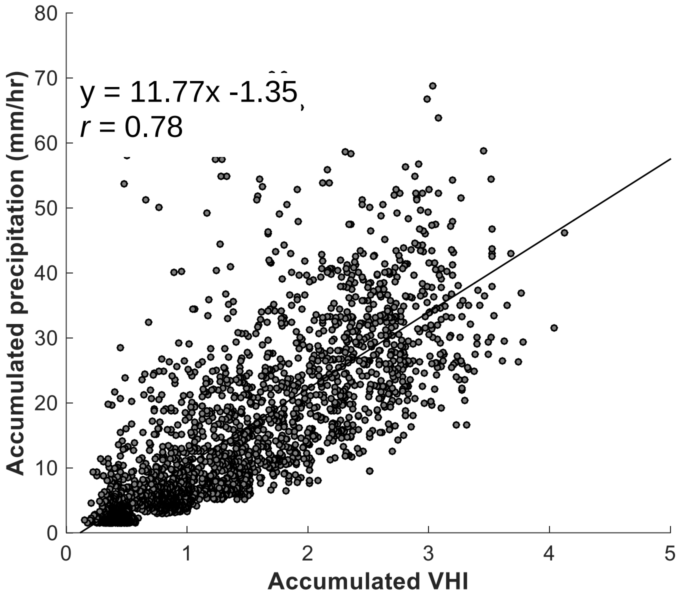

Figure 2. Correlation between accumulated VHI and AMSR2 precipitation for: (a) 2013, and (b) 2014.

The VHI results (values from 0 to 1) were regrouped into four categories to present different levels of drought: severe drought (0–0.2); moderate drought (0.2–0.3); slight drought (0.3–0.4); and normal (0.4–1). In general, the severe and moderate droughts were spatially scattered over the study region but were more common in areas along the Pacific coast, while the slight drought and normal conditions were more commonly distributed in forested areas in the middle region and along the Atlantic coast. The temporal evolution drought trends showed that the spatial distributions of moderate and serve droughts occurred from the early dry season (December) and returned to normal or wet conditions by the end of dry season (April) or the early rainy season (May) with the onset of rainfall.

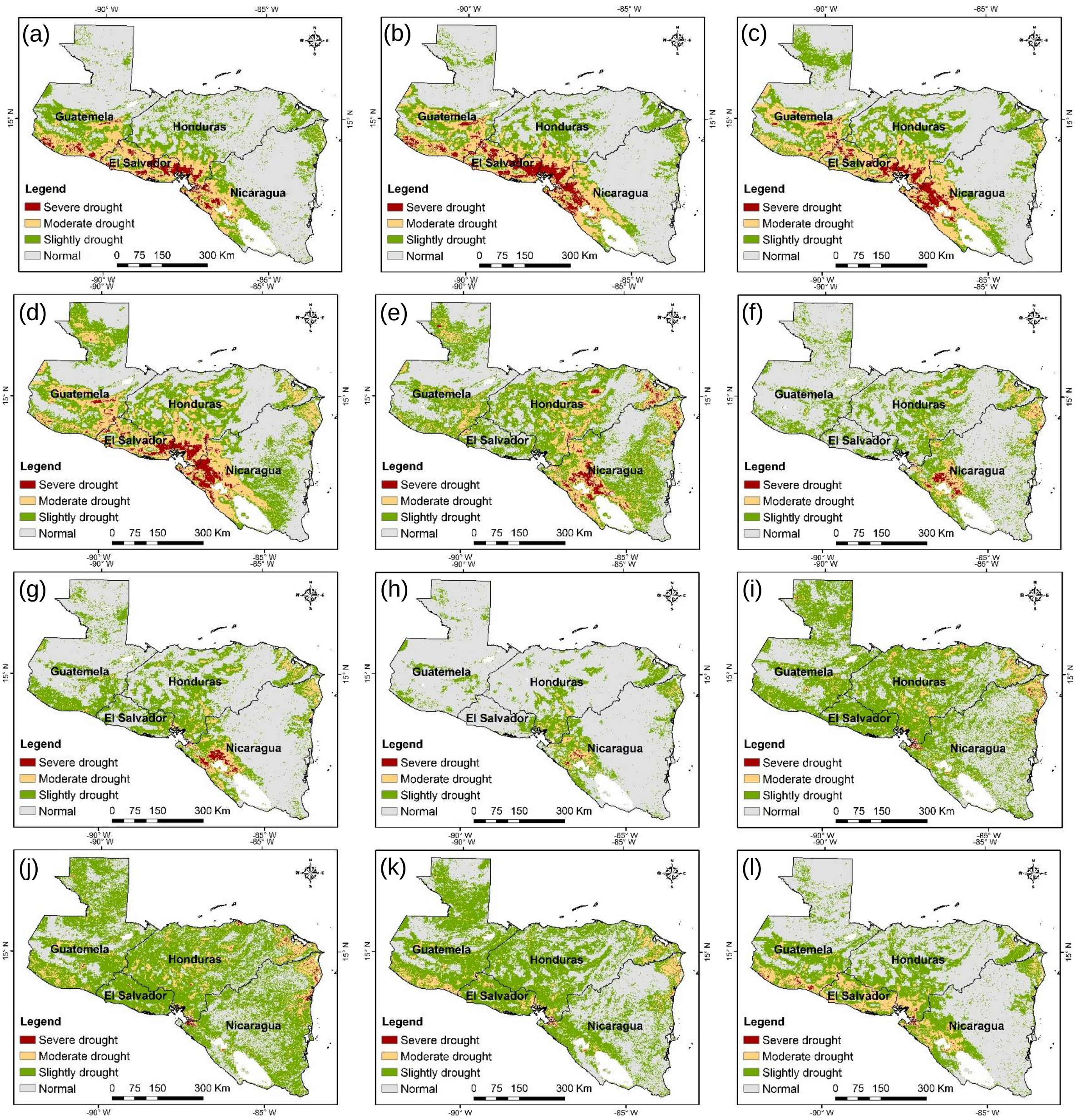

Figure 3. Spatiotemporal distributions of droughts from January to December in 2014.

The research findings obtained from this study drew attention to the plight of farmers in the study region that the pronounced rain deficit during (April–May) due to droughts and June–July could have a detrimental impact on crop production during the most sensitive stages of crop development in the primera and postrera seasons. The impacts of drought might lead to increased market food prices in response to crop production shortages. Thus, policymakers could evaluate this issue to avoid possible negative impacts on crop production and issues of food security in the region.

6. CONCLUSIONS

This study confirmed the validity of our approach for drought monitoring in Central America using MODIS data. The close relationship between VHI results and AMSR2 precipitation data confirmed the consistency between these two datasets. The moderate and serve droughts were generally distributed in areas along the Pacific coast. Drought began in early dry season and returned to normal conditions with onset of the rainy season. The methods used in this study demonstrate the application of MODIS data for drought monitoring. The results could provide quantitative information of droughts in the study region, which important for planners to form strategies to mitigate possible drought effects on crop production.

References

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