IDENTIFYING DROUGHT AFFECTING PADDY LAND IN URBAN AGRICULTURE AREA USING REMOTE SENSING AND ACTUAL OBSERVATIONAL PRECIPITATION DATA: A CASE STUDY IN HOA VANG DISTRICT, DANANG CITY, CENTRAL VIETNAM

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ABSTRACT

Agricultural production is one of the most vulnerable areas affected by drought. Rice is one of most sensitive crop to drought in Central Vietnam. Therefore, identifying drought affect paddy land area are very important because this data can support policy-makers in planning and management of paddy land and water resources. In this context and with limited in-situ data available at local level, remote sensing provides valuable opportunities for drought assessment. This study aimed to identify drought affect paddy land area in Hoa Vang district, Danang city based on combining remote sensing and observation data of precipitation. The drought level was calculated by Standardized Precipitation Index - SPI from daily rainfall data collected of 4 actual observation stations and 4 simulation stations from remote sensing images during 1997-2016. The SPI calculated shows that drought occurred mainly in the Summer-Autumn crop season from May to August, of which drought occurred in almost communes of the district in June and July. The results of spatial interpolation IDW method are 6 maps of drought level affected paddy land area using the Summer-Autumn SPI in 2002, 2006, 2010, 2011, 2015 and 2016; and statistical data of drought level distributed in paddy land in the district. The drought was distributed in all 11 communes in Summer-Autumn crop season. The combination of observed and simulated precipitation data were increase accuracy of simulation drought effect on paddy land in regions of low-density observation networks.

1. INTRODUCTION

The Intergovernmental Panel on Climate Change (IPCC) warned about the possible intensification of droughts in this century, especially in some areas such as the Mediterranean basin (IPCC, 2014). Within this context, in recent years and in several areas of the world, drought events have been widely described and analyzed. Regional drought events have been analyzed in some of the major large-scale in over the world. Drought studies at a national scale have also been performed in Central Vietnam. Drought indices are a useful tool for monitoring and assessing the different kinds of drought. The SPI is the most applied index to analyze meteorological drought defined as temporary lower-than-average precipitation which results in diminished water resources availability, impacting on economic activities, human lives, and the environment (Bayissa *et. al.,* 2015). This can be considered one of the most robust and effective drought indices, as it can be evaluated for different time scales and allows the analysis of different drought categories (Capra *et. al.,* 2012). Moreover, the SPI is based on precipitation alone, and is thus easier to calculate than more complex indices. Therefore, this index is recommended by the World Meteorological Organization for drought studies (WMO, 2012) and has been used by many researchers in the world and in Vietnam *(*Monica *et. al.,* 2016*;* Moreira *et. al.,* 2015; Chuong *et. al.,* 2015; Phuong *et. al.,* 2015; Ngu *et. al.,* 2017). In that context, people's livelihoods in the Hoa Vang district of Danang city still depend on agricultural production, one of the areas most affected by drought. Rice is one of most sensitive crop to drought in this district. This study was conducted to determine the effect of drought on paddy land area in Hoa Vang district, that characterized by urban agriculture area, by SPI value. To minimize problems with interpolation in regions of low-density observation networks, a

combination of rain gauge datasets from remote sensing and actual observation is proposed for the study area.

2. MATERIALS AND METHODS

2.1. Study areas

Hoa Vang is the only agriculture district of Danang city, located in 7 km from the city center. This district comprises 11 communes with a total natural area of 73,317.2 ha, of which 64,879.5 ha is agricultural land, accounting for 88.28% of the total land area. The terrain of district is diverse, extending over three regions: mountainous, midland and flat land, divided into three types of terrain: The mountainous region is comprised of Hoa Bac, Hoa Ninh, Hoa Phu and Hoa Lien communes with the height from 400 to 500m, covering an area of 78.66% of the total natural land area of whole district. The midland region is characterized by semi-mountainous terrain, consisting of relatively low hills and low mountain front plains, mostly low hills with an average elevation of 50 to 100 m, alternating with narrow fields, including Hoa Phong, Hoa Khuong, Hoa Son and Hoa Nhon communes, accounting for 17.18% of the total natural area of the district; The flat region has an average height of 2 to 10m, concentrated in Hoa Tien, Hoa Chau and Hoa Phuoc communes, occupying 4.16% of total natural area.

2.2. Materials

Precipitation data

The actual observation precipitation data from 1997 to 2016 of Da Nang, Tam Ky, Thuong Nhat and Ai Nghia stations were collected from the Mid Central Hydro-Meteorological Station. The simulation precipitation data were derived from the Tropical Rainfall Measurement Mission (TRMM) to enhance the rainfall stations for interpolation of drought in the study site. Rainfall data from TRMM remote sensing data used in this study is available from http://waterdata.dhigroup.com.

Remote sensing images

The RapidEye image is a high resolution satellite image that has spatial resolution is only 5 meters. The ID of four scenes including 4946401_2016-04-13_RE1_3A_649882; 4946501_2016-04-13_RE1_3A_649882; 4946402_2016-04-26_RE5_3A_649882; 4946502_2016-04-26_RE5_3A_649882 were acquired in April 2016. This data has been contributed on behalf of the German Aerospace Center (DLR) through funding of the German Ministry of Economy and Energy under the project “RapidPlanning” (grant identifier 01LG1301K) and the Department of Geography, University of Tuebingen, Germany.

A series of Landsat satellite images were downloaded from USGS via http://glovis.usgs.gov/ including: Landsat ETM 7 was acquired in 2002 (ID: LE07_L1TP_124049_20020513_20170130_01_T1), Landsat TM 5 was acquired in 2006 (ID: LT05_L1TP_124049_20060719_20161120_01_T1), Landsat TM 5 was acquired in 2010 (ID: LT05_L1TP_124049_20100612_20161015_01_T1),), Landsat TM 5 was acquired in 2011 (ID: LT05_L1TP_124049_20110615_20161009_01_T1), Landsat 8 was acquired in 2015 (ID: LC08_L1TP_124049_20170311_20170317_01_T1). These scenes were selected based on SPI calculated results.

Field data

Prior to image classification and accuracy assessment, a field survey of paddy rice fields cultivated in Summer-Autumn season was conducted from May to June in 2016 to obtain training and validation datasets. An ancillary field campaign was also conducted during rice

maturity and harvest in July and August 2016. There are 175 points within paddy rice area obtained using handheld GPS devices from the 2016 field survey.

2.3. Methods

2.3.1. Satellite images classification method

The RapidEye images were collected at 3A, geometrically corrected, thus the subject was manipulated geometry for all Landsat satellite images. Using the district and commune boundary maps of Hoa Vang district that was extracted from the Map of current land use in 2015 to clip Landsat TM5 and RapidEye remote sensing imagery.

Supervised Classification with Maximum Likelihood algorithm has been used to interpret a series of remote sensing images. This study was used the classification error matrix to determine the accuracy of image interpretation, the results are based on total accuracy and Kappa Coefficient (K). The K value is from 0 to 1, K >0.8 represent strong agreement and good accuracy, K = 0.4 – 0.8 is middle accuracy, and K < 0.4 is poor accuracy.

2.3.2. Drought assessment method using Standardized Precipitation Index (SPI)

The SPI was designed to quantify the precipitation for multiple timescales. These timescales reflect the impact of drought on the availability of the different water resources. The SPI can be calculated from 1 month up to 72 months. Shorter timescale SPIs such as 1-, 2- or 3-months, can provide early warning of drought and help assess drought severity (Mckee *et. al.,* 1993). The SPI is calculated by the formula (1):

$$SPI = \frac{R - \bar{R}}{\sigma} \quad (1)$$

The SPI for all the months within a drought event can be termed the drought's "magnitude": $2 \leq SPI \leq 3$: extremely wet; $1.5 \leq SPI \leq 1.99$: very wet; $1.0 \leq SPI \leq 1.49$: moderately wet; $-0.99 \leq SPI \leq 0.99$: near normal; $-1.0 \leq SPI \leq 1.49$: ; $-1.5 \leq SPI \leq -1.99$: severely dry; $-2 \leq SPI \leq -3$: extremely dry (WMO, 2012).

2.3.3. The Inverse Distance Weighting (IDW) interpolation method

Inverse Distance Weighting (IDW) method was used to interpolate rainfall values of 4 actual observation stations and 4 simulation stations to make a spatial distribution of drought map in the study area.

3. RESULTS

3.1. Drought situation using Standardized Precipitation Index - SPI

With the objective assessing drought effects on paddy rice cultivation area, this study only calculates the SPI value for 1-month during the Summer-Autumn and Winter-Spring paddy rice crop. In Hoa Vang district, the Winter-Spring season starts from December to April, and the Summer-Autumn season starts in mid-May and ends in August of the same year. The results of SPI calculation in the Winter-Spring paddy rice crop showed that at all 4 observation and simulation stations were in the range of moderately wet to near normal. There are very rare SPI values at severely dry appear in the Winter-Spring in the district. The results of SPI calculation in Summer-Autumn paddy rice crop shows that drought was not occurred much in May and August, only in 2002 at Ai Nghia station and Thuong Nhat station. However, SPI value at Da Nang station appeared extremely dry and severely dry in 2012. Meanwhile, the drought appears at extremely dry and severely dry levels in 2014 and 2015 at Thuong Nhat station in June, Tam Ky station in July.

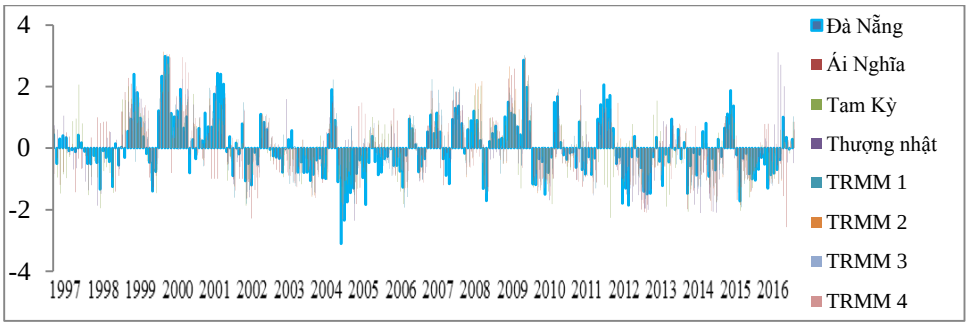

Figure 1. *The results of SPI value for 1-month from 1997 to 2016*

The SPI data of all 8 stations in Figure 1 shows the year of drought occurred including 2002, 2005, 2006, 2010, 2012, 2014, 2015 and 2016. However, this study only use remote sensing images of 6 years due to the images in 2005 and 2014 are of poor quality.

3.2. Spatial distribution of drought using remote sensing and actual observational precipitation data

The total classification accuracy and Kappa coefficient of remote sensing images in the drought years are presented in the table 1.

Table 1. *Total accuracy and Kappa coefficient*

Year	Total accuracy (%)	Kappa coefficient
2002	86.69	0.82
2006	87.61	0.83
2010	87.91	0.87
2011	85.75	0.81
2015	86.10	0.82
2016	91.25	0.89

The data in the table 1 shows that total accuracy of RapidEye image in 2016 was highest. Meanwhile, total accuracy of Landsat TM5 in 2011 was lowest. The total accuracy of the remaining years is in the range from 86% to 87%. The Kappa coefficient value of 6 images represent strong agreement and good accuracy.

These images were converted to ArcGIS software to create map of the current paddy rice land. In order to simulate the effect of drought on paddy rice cultivation area, this study used SPI data of 4 observation stations at 1-month in the Summer-Autumn crop to interpret spatial distribution of drought in paddy rice land use map in 2016 by IDW interpolation method on ArcGIS 10.2.2 the software. The results of the spatial distribution of the drought in the study site during Summer-Autumn crop are illustrated in Figure 2.

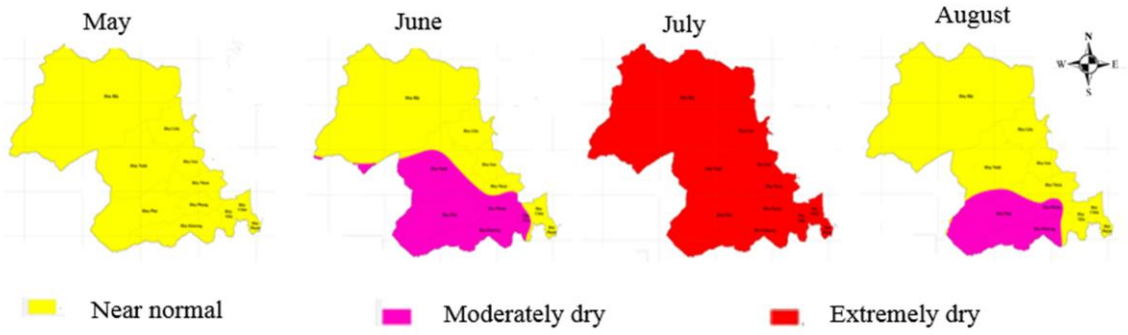

Figure 2. *The spatial distribution of the drought from 4 actual observation stations*

In order to verify the accuracy of drought situation from the spatial interpolation method of the 4 observation stations, this study was conducted in comparison with the report on paddy rice land that can not be produced due to lack of water in the district. The report was collected

from the District's Agriculture and Rural Development Division in combination with field survey method. The results of review and comparison data show that there is no extremely drought in July as the interpolation results showed in the figure 2. In June, drought occurred in some mountainous communes, while the results of IDW method from 4 actual observation stations showed the drought was occurred in the flat areas at moderately dry level.

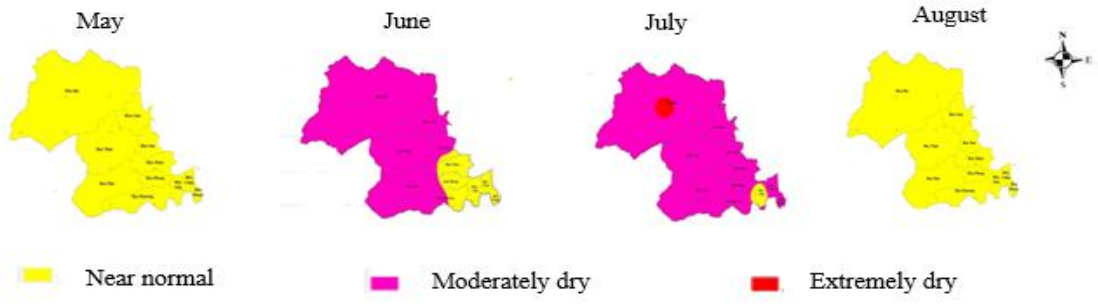

Figure 3. *The spatial distribution of the drought from combining 4 actual observation stations and 4 remote sensing stations*

It can be seen that the results of simulating spatial distribution of drought in a regions lack of observation stations within its boundaries are inaccurate. Therefore, the rainfall data of 4 observation stations were combined with 4 simulators from the remote sensing source were used to interpreter of drought spatial distribution in this study.

3.3. Drought affecting paddy rice land in Hoa Vang district

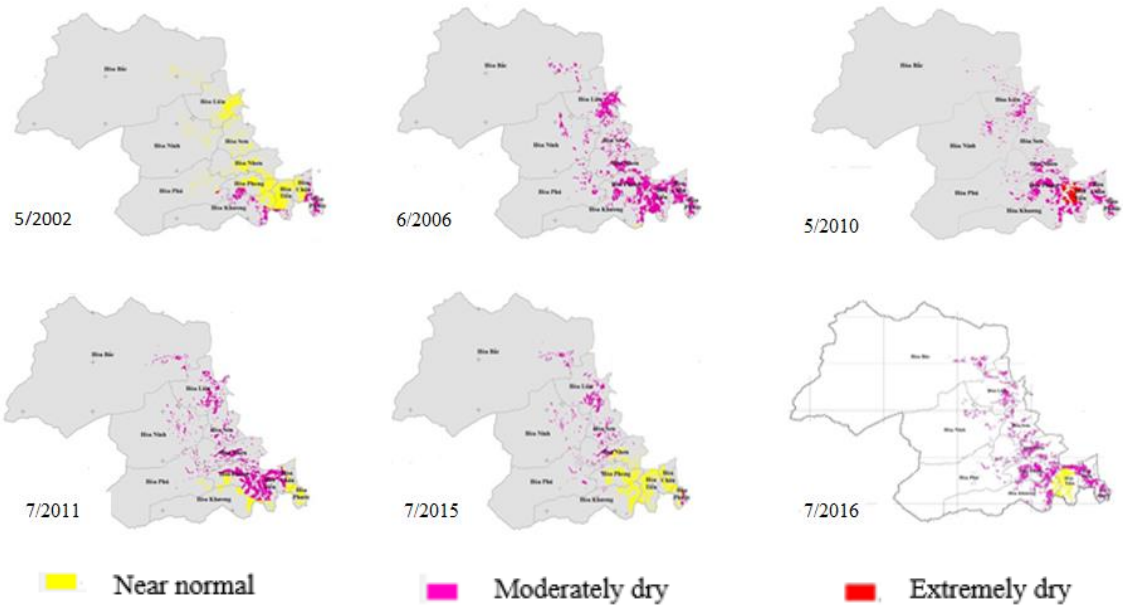

Figure 4. *Drought effect on paddy rice land area*

The information from figure 4 illustrate that in the summer-autumn 2002, 2006, 2010, 2011, 2015 and 2016 almost all drought occurs. The paddy rice area affected by drought accounts for almost all of the total land paddy rice area. In particular, there is more than 99% of the paddy rice area was affected by drought in 2006. By 2015, the area of paddy fields affected by drought is the lowest in three years, but still accounts for 33.7% of the total paddy rice area. It can be seen that the effect of drought on paddy land in the Summer-Autumn crop is relatively strong.

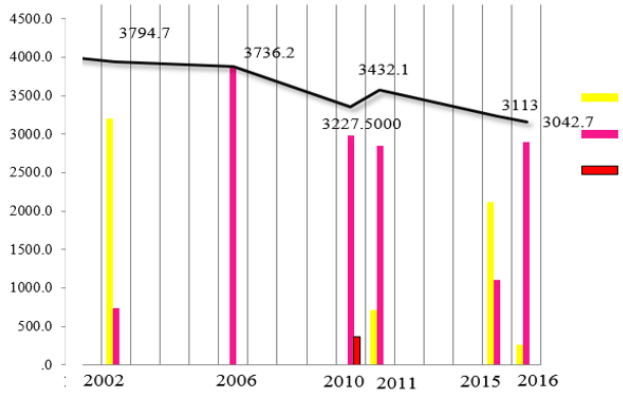

***Figure 5**. Drought occurred in paddy rice land*

The data in figure 5 demonstrate that the most severe drought occurred in 2006 that effected to 3736.2 ha of paddy rice land. It is noteworthy that severe drought was occurred in 2010 with affect to nearly 500 ha of paddy rice land. The effect of drought on rice land in Hoa Vang district does not follow a certain rule, sometimes it occurs in the mountainous and midland communes but at other times concentrated in the flat region communes.

4. CONCLUSION

In summary, this study reinforces the importance of remotely sensed precipitation estimates, in particular TRMM products, combination with surface observations for identifying drought affecting paddy land in urban agriculture area. The study results show that drought occurred mainly in the Summer-Autumn season from May to August, of which drought occurred in all communes of the district in June and July. The results of spatial interpolation IDW method are 6 maps of drought level distribution on paddy land based on the Summer-Autumn SPI in the year of 2002, 2006, 2010, 2011, 2015 and 2016 and statistical data of drought area of paddy land in Hoa Vang district. The drought was distributed in all 11 communes in Summer-Autumn crop.

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