EVALUATION OF AGRICULTURAL DROUGHT USING LSWI, MSI INDICES: CASE STUDY IN THUAN NAM DISTRICT, NINH THUAN PROVINCE

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Abstract: *This study was applied Land Surface Water Index (LSWI) and Moisture Stress index (MSI) based on Landsat-7, Landsat-8 images data from the 2004-2016 period to observe and evaluate drought situations in Thuan Nam district, Ninh Thuan province. The results show that LSWI and MSI reflect the level of drought consistent with the drought events recorded from the ground monitoring station data in the years 2004-2005, 2015-2016. This paper proposes that LSWI, MSI can be used to monitor agricultural drought, as well as use these two indices for building drought prediction models.*

Keywords: *LSWI, MSI, agricultural drought, Thuan Nam.*

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1. INTRODUCTION

Drought is a complex natural phenomenon, usually due to a lack of rainfall that leads to a decrease in soil moisture content and affects crop growth and development. Droughts also often cause serious impacts on socio-economic systems (Wilhite, 2005). Droughts are often classified into four types of drought such as meteorological drought, hydrological drought, agricultural drought and socioeconomic drought.

In general, in all of the above types of drought, the origin of drought comes from the lack of rainfall, leading to a lack of soil moisture, a decrease in hydrological flow, resulting in water shortages for agricultural, industrial, service and domestic water needs. Especially, in the context of global climate change, the intensity and frequency of drought events are

increasing and the level is more serious. Therefore, monitoring and forecasting drought is considered a decisive factor to prevent and mitigate the impacts of drought.

There are many different approaches to drought identification, monitoring, evaluation and prediction. However, the most popular approach today is the approach based on drought indicators and indices. According to this approach, scientists often construct drought indices based on meteorological station data or remote sensing data (Nadi and Ghorbani., 2015; Hao et al., 2017, Zhao et al., 2016; Mannanva V.K. Sivakumar et al., 2010).

Several drought indexes have been developed and widely used, such as Palmer drought severity index, Standardized Precipitation index (SPI), Crop Moisture index (CMI) (Silvakuma et al., 2010). These indices often provide relatively accurate estimates of agricultural drought at research sites. However, there are some limitations that, due to the uneven distribution among hydro-meteorological stations within a region or between geographic regions, there is a lack of data to calculate for the above indices in the above regions. different positions.

Recently, the strong development of remote sensing technology has provided huge data sources of observing the earth's surface on many different resolutions. With the expansion of remote sensing data sources, many remote sensing-based drought indices have emerged and rapidly developed such as Normalized difference vegetation index (NDVI), Normalized Difference Water Index (NDWI), Land Surface Water Index (LSWI), and Moisture Stress Index (MSI) and so on, is recommended and widely applied in monitoring and evaluation of agricultural drought on the world (Hazaymeh and Hassan., 2017; Du et al., 2018; Zhang et al., 2013; Bajgain et al., 2015; Hung and Hoai., 2015). In general, these indices quietly give good results and are close to the actual drought.

Thuan Nam is the furthest local of Ninh Thuan province, has typical savanna climate characteristics in Vietnam, the average annual rainfall is less than 600 mm / year, the climate is very dry and hot. This is also the driest locality in our country, often having prolonged droughts, in which prolonged droughts took place in 2004, 2005, 2006, 2015, 2016 are considered as Record drought was recorded over the past 15 years. The extent of the impacts of these droughts occurs on a large scale, causing local water shortages in many localities, affecting the livelihoods and lives of local communities [Le Van Ha, 2019]. This study applies the drought indices based on the Landsat-7, Landsat-8 images data from the 2004-2016 to assess drought events, as well as compare the research results with the drought indices based on the meteorological station as (SPI) and recorded drought events.

2. CONTENT

2.1. Material and Methods

2.1.1. Study area

The study area is Thuan Nam district, stretching from $108^0$39'7 " to $109^0$1'18 " East longitude and $11^0$18'21 " to $11^0$35'50' North latitude, bordering Ninh Phuoc district in the north (Ninh Thuan province), the south by Tuy Phong district, Binh Thuan province, the west by Ninh Son district, Ninh Thuan province and the east by the East Sea (Figure 1).

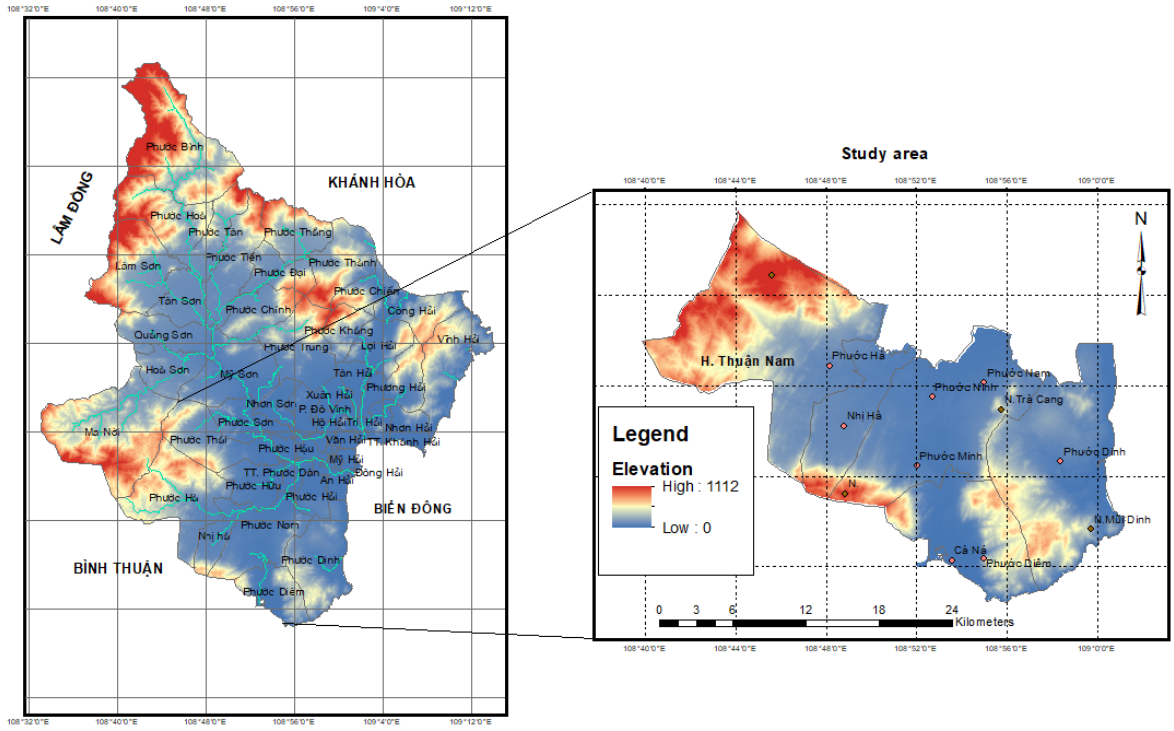

Fig 1. *Map of study area for agriculture drought caculation*

The area total of the study area is about 563.33 km2, including 8 administrative units (Phuoc Ha, Nhi Ha, Phuoc Nam, Phuoc Minh, Phuoc Dinh, Phuoc Diem and Ca Na). According to the 2017 Statistics, the population in the study area is 59,644 people, the average population density is about 105 people/km2, with three ethnic groups living together (The Kinh, The Cham and The Raglai).

The topography of the study area is complicatedly divided with three surfaces that are all hilly, sand dunes stretching along the coastline and in the direction of the meridian forming barrier walls around small and narrow plains. Some typical high mountain ranges, such as Cha Bang Mountain, Da Bac Mountain (644m), Ba Be and Mui Dinh, Gio Mountain (897m), Ham Ech Mountain, Tra Cu Mountain, to the massive massif extending to the

mountain Chao Tu - upstream of Bieu River and Cha Bau mountain (919m) belongs to the upper reaches of Gia river (Ya stream). These mountains are largely composed of granite so the soil layer is quite thin and covered with a poor vegetation cover, mainly semi-deciduous forest and shrubs.

The average annual rainfall fluctuates from 700 to 850mm, low rainfall year is only 450-550mm, while the average evaporation can reach 1,700 mm and the air humidity is relatively low, only reaching 75-77%. Figure 2 shows that the rainfall is concentrated mainly in 3 months (September, October, November), while January, February, March, April and May hardly rain. In general, the ecological environment in the study area is relatively sensitive with water shortages frequently occurring in the dry months.

Corresponding to the dry climate, the vegetation cover in the study area are quite typical for this climate type with typical vegetation such as wetlands, barn, broadleaf closed forests, plantations and coloration:

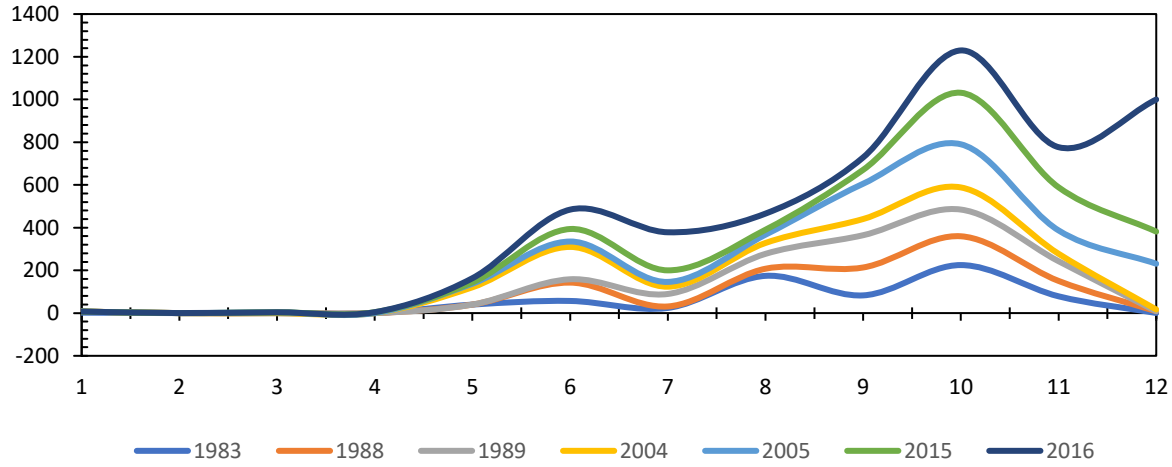

Fig 2. *Average monthly rainfall in the years with the severe drought in Phan Rang Station (mm)*

(1) Woodland and grassland vegetation cover is the ecological succession after the forest cover has been changed or fully exploited due to human impacts. The remaining vegetation cover today is mainly grasslands and shrubs. Grasslands and shrubs are often distributed in low mountainous and hilly areas, mainly small trees, shrubs, small leaves to cut leaves, cactus plants.

(2) The second vegetation cover is a humid tropical green forest all year round. This is the remaining vegetation layer in the 800-1000m altitude, distributed mainly in the watershed area of Tan Giang lake in Phuoc Ha and Nhi Ha communes. However, this forest type is not much (about 27 thousand ha), mainly regenerated forest with low timber volume.

(3) The third vegetation cover is planted vegetation cover: planted forests and cash crops. Plantations are mainly casuarina and oval trees. This vegetation covers about 15 thousand hectares. Food crops and crops such as rice, corn, potatoes, legumes; Fruit trees such as custard apple (na), grapes, apples, etc.

In summary, forest land in Thuan Nam accounts for more than 49% of the total natural area and most of the study area is arid and semi-arid. Sand deserts, arid regions, and high, low and high elevation forest ecological regions are all characterized by a dry climate, relatively low annual rainfall, and relatively high desertification risk.

2.2. Data

Multi-time Landsat 7 & 8 satellite image data is used to calculate LSWI, MSI, image acquisition period from 2004-2016, image resolution is 30x30m. Landsat image data sources are collected from the US Geological Services website at *https://earthexplorer.usgs.gov/*.

Table 1. *Wavelength and resolution of Landsat 7 and Landsat 8 images*

Landsat-7 ETM		**Landsat-8 OLI and TIRS**	
Bands	**μm)**	**Bands**	**λ(μm)**
Band 1 - Blue (30m)	0.441-0.514	Band 1 - Coastal/Aerosol	0.435 - 0.451
Band 2 - Green (30m)	0.519-0.601	Band 2 - Blue	0.452 - 0.512
Band 3 - Red (30m)	0.631 – 0.692	Band 3 - Green	0.533 - 0.590
Band 4 - NIR (30m)	0.772 – 0.898	Band 4 - Red	0.636 - 0.673
Band 5 - SWIR-1(30m)	1.547 – 1.749	Band 5 - Near Infrared	0.851 - 0.879
Band 6 - TIR (60m)	10.31 – 12.36	Band 6 – SWIR-1	1.566 -1.651
Band 7 - SWIR-2 (30m)	2.064 – 2.345	Band 7 – SWIR-2	2.107 - 2.294
Band 8 - Pan (15m)	0.515 – 0.896	Band 8 - Pan	0.503 - 0.676
		Band 9 - Cirrus	1.363 - 1.384
		Band 10 - TIRS-1	10.60 - 11.19
		Band 11 - TIRS-2	11.50 - 12.51

This study also used data from hydro-meteorological stations collected in Phan Rang, Nhi Ha, and so on, and the National Center for Meteorology and Hydrology to compare the remote sensing-based agricultural drought index, SPI and the ground meteorological station data.

2.3. Methodology

Land Surface Water Index (LSWI) has been used in many studies, assessing agricultural drought (Xiao et al., 2002; Zhang et al, 2013; Abdel-Aziz Belal et al., 2014). Land Surface Water Index (LSWI) was calculated by equation (1)

$$LSWI_{\text{Landsat 7,8}} = \frac{NIR - SWIR1}{NIR + SWIR1} \quad (1)$$

Table 2. *LSWI-based drought categories Source: Bajgain et al. (2015).*

Drought class	Description
LSWI> 0.1	Non-drought or abnormally dry
0<LSWI<= 0.1	Drought-moderate
-0.1<LSWI<= 0.1	Drought-severe
LSWI<= -0.1	Drought-extreme

In the Landsat-7 image, NIR is the band 4 (0.772 - 0.898), SWIR-1 is the band 5 (1.547 - 1.749). Whereas, in the Landsat-8 image, NIR is the band 5 (0.851 - 0.879), SWIR-1 is the band 6 (1.566 - 1.651). The LSWI values range from -0.1 to 0.1, divided into four levels (figure 1.1).

The MSI is a water ratio index for the estimation of leaf relative water content (%) and equivalent water thickness (Zhang et al., 2013). In this paper, band 5, 6 of Landsat 8, band 4, 5 of Landsat 7 data is used. Moisture stress index (MSI) was calculated by equation (2).

$$MSI_{\text{Landsat 7, 8}} = \frac{NIR}{SWIR-1} \quad (2)$$

The value of MSI is ranges from 0-4, usually classified into 5 levels according to Table 3.

Table 3. *MSI-based drought categories*

Drought class	Description
0 < MSI < 0.8	Non-moisture stress
0.8 < MSI < 1.60	Low-moisture stress
1.60 < MSI < 2.40	Moisture stress-moderate
2.4 < MSI < 3.20	Moisture stress-severe
3.20 < MSI < 4.0	Moisture stress-extreme

2.4. Results and discussion

The results of calculating LSWI based on the data of Landsat 7 & 8 in the years 2004, 2005, 2015, 2016 on fig 3 show that most of the area of Thuan Nam district is in the range of drought- extreme (LSWI <= -0.1), only the territorial part in Phuoc Ha, Nhi Ha and Phuoc Diem communes (the area with broad leaved closed forest vegetation) is corresponding to the medium drought or non-drought (0<LSWI<=0.1), which corresponds to the purple color in figure 3).

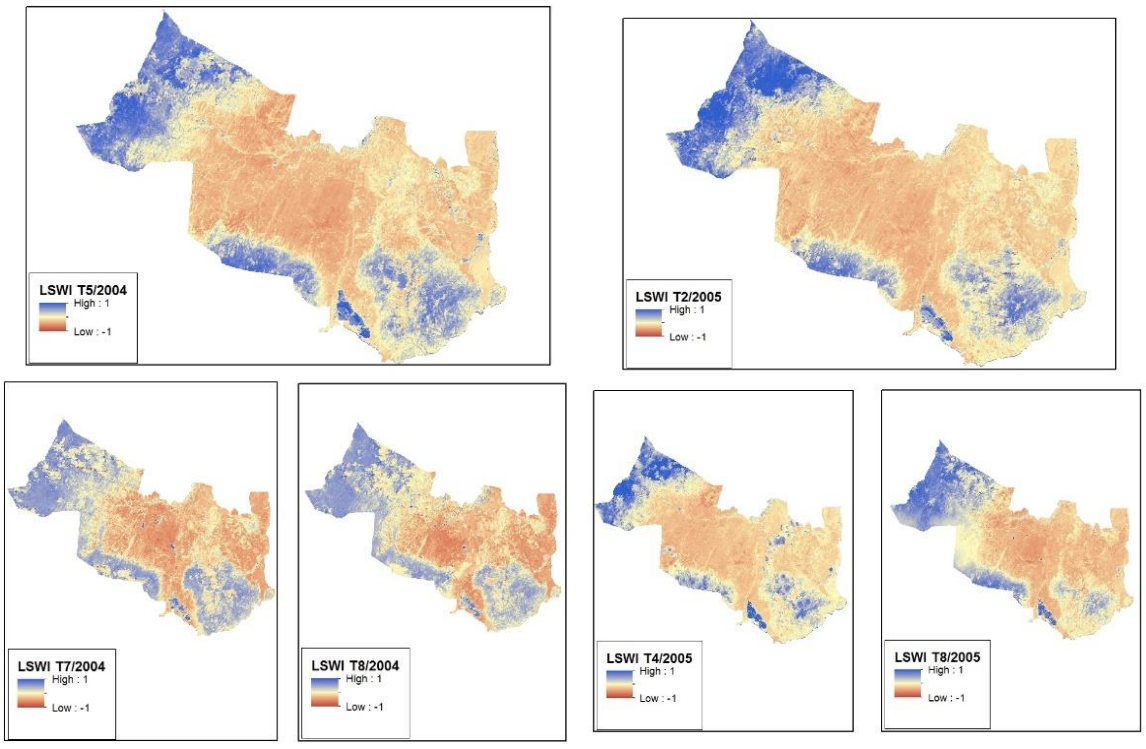

Fig 3. *Final LSWI map calculated from Landsat-7 images on May, July, August 2004; on February, April, August 2005*

While, Figure 4 show that the drought level of 2015, 2016 years is lower than in 2004 and 2006 years, the LSWI value ranges from -0.4 - 0.5. According to the scale of drought scale in Table 2, most of the study area is severely drought. The drought area is mainly coastal sand dunes, the central area of the district. The time of drought usually falls in the period from February to July, with years lasting until September.

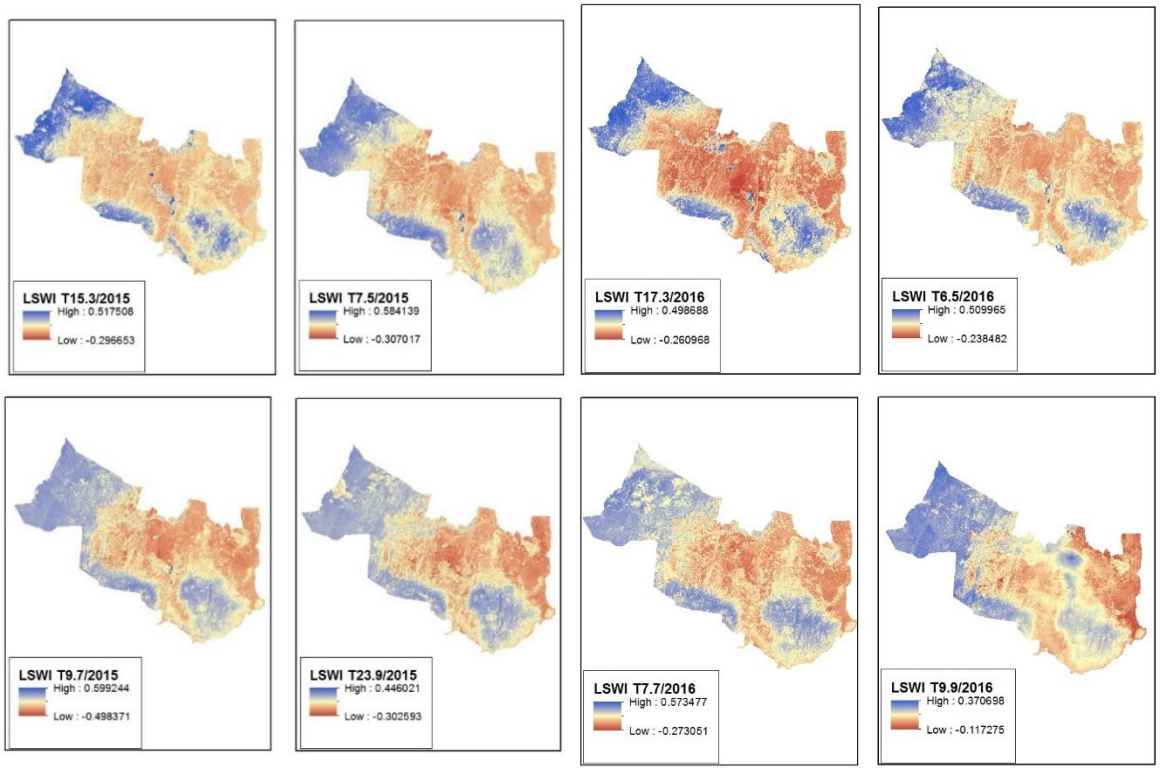

Fig 4. *Final LSWI map calculated from Landsat-8 images on March, May, July, September 2015; on March, May, July, Setember 2016.*

This result is quite similar to the ground observation data in the study period (Fig 5, Fig 2), the year of heavy drought also fell in 2004, 2005, 2015 and 2016. In these years, the yearly average rainfall is only 420 - 550 mm.

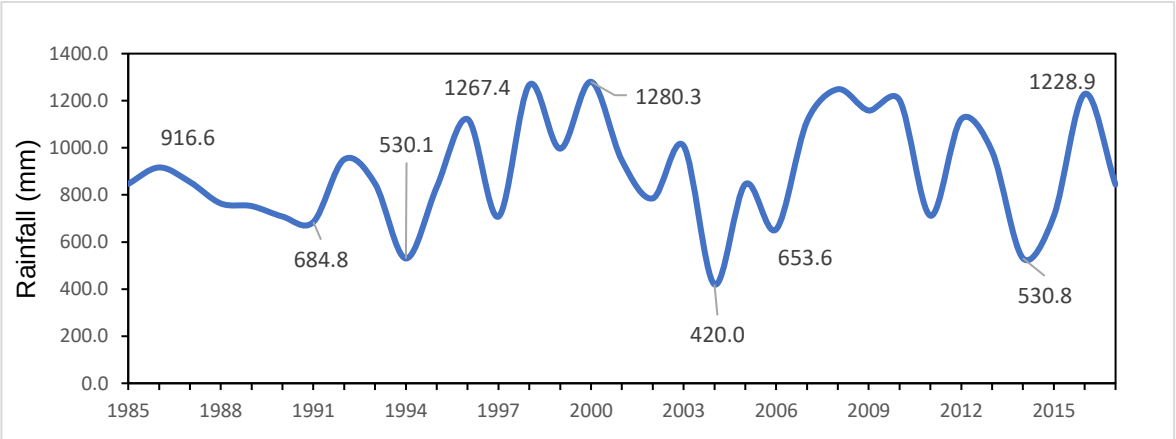

Fig 5. *Average annual rainfall at Nhi Ha station in the period 1985-2017.*

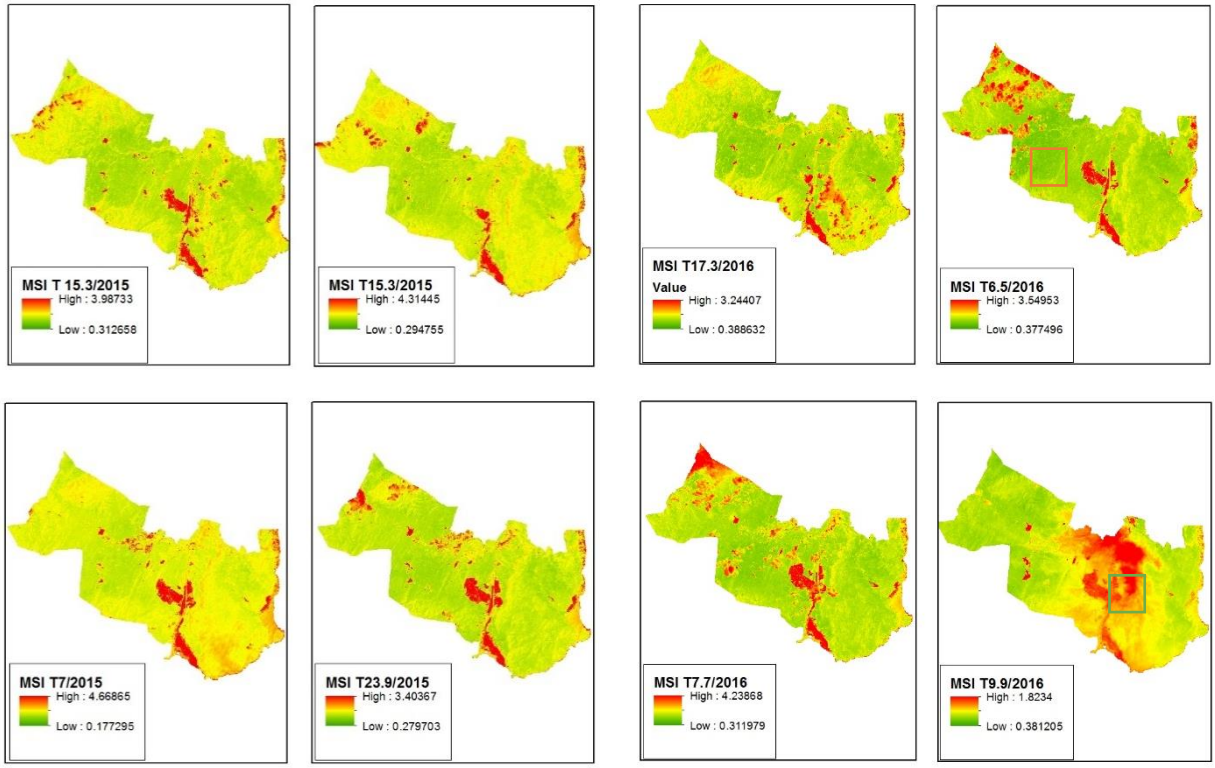

Fig 6. *Final MSI map calculated from Landsat-8 images on March, July, September 2015; on March, May, July, Setember 2016.*

Unlike the results of calculating the LSWI, the map of the spatial distribution according to the MSI (Fig 6) shows that, in July 2015, drought-extreme area accounted for a very small, most of the area shown above the map is drought-moderate or non-drought. This is in contrast to the results on the LSWI map in July 2015. While on the MSI map in September 2016, the limit corresponds to only 2 level (Moisture stress-moderate).

Meanwhile, the results of calculating the SPI - 6 months, SPI- 12 months (Le Van Ha, 2018) also showed that the SPI value coincided with the LSWI and was consistent with the worst years of drought recorded in Thuan Nam district, on 2004, 2005, 2015 and 2016 years. From the results, the comparison between the LSWI and MSI indexes can be seen that the LSWI index more closely reflects the reality of drought at the study site and is more similar to the results observed at ground measuring stations.

3. CONCLUSION

Agricultural drought is a type of natural disaster that frequently occurs in Thuan Nam district, causing a great impact on the livelihood security of the people. Therefore, the agricultural drought needs to be controlled and managed effectively. To control and manage

agricultural drought, many agricultural term indices have been developed, LSWI, MSI are among them.

The drought indices based on remote sensing data are a good supplement to research, assess the drought and learn drought history. Remote sensing data is often continuous and easily updated. In this study, the remote sensing data showed that the degree of drought in Thuan Nam district is relatively severe, the results of the calculating and mapping drought are relatively consistent with the ground observation data. The areas prone to drought are the central area (Phuoc Ninh, Phuoc Minh) and the coastal area (Phuoc Dinh and Phuoc Diem). Less arid areas are the communes of Phuoc Ha and Nhi Ha. However, the research results show that LSWI correctly reflects drought conditions in the study area. From the result, the article recommends using LSWI in assessing agricultural drought and conducting more studies in other areas to pilot.

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ĐÁNH GIÁ HẠN NÔNG NGHIỆP SỬ DỤNG CHỈ SỐ LSWI, MSI: NGHIÊN CỨU TRƯỜNG HỢP Ở HUYỆN THUẬN NAM, TỈNH NINH THUẬN

Tóm tắt: *Nghiên cứu này áp dụng các chỉ số áp lực nước bề mặt (LSWI) và chỉ số áp lực độ ẩm (MSI) dựa vào dữ liệu ảnh Landsat 7&8 giai đoạn từ năm 2004-2016 quán sát và đánh giá tình hình hạn hán ở huyện Thuận Nam, tỉnh Ninh Thuận. Kết quả nghiên cứu cho thấy, chỉ số LSWI và MSI đã phản ảnh mức độ hạn hán khá phù hợp với sự kiện hạn hán diễn được ghi nhận từ dữ liệu trạm quan trắc mặt đất và số liệu điều tra thu được tại huyện Thuận Nam, tỉnh Ninh Thuận trong các năm 2004-2005, 2015-2016. Kết quả nghiên cứu này cũng cho thấy, LSWI, MSI có thể sử dụng để giám sát hạn nông nghiệp, cũng như sử dụng hai chỉ số này cho xây dựng mô hình dự báo hạn hán.*

Từ khóa: *LSWI, MSI, hạn nông nghiệp, Thuận Nam.*