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# DROUGHT RISK ASSESSMENT DURING THE DRY SEASON IN TIEN RIVER ESTUARY

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**Abstract**. Drought simply is a period of moisture deficiency. It depends on temperature, evaporation capacity, vegetation cover, topography, etc., in addition, it often happens on a large scale making it difficult to use traditional research methods. With the development and widespread application of remote sensing technology and geographic information systems (GIS), the use of satellite images as well as GIS software is becoming more and more effective in monitoring, monitoring and assessing drought. In this study, the author assessed the risk of drought at Tien river estuary through two indices: Normalize Difference Vegetation Index (NDVI) and Standardized Precipitation Index (SPI) during the dry season months of 1991, 2001, 2010 and 2018. SPI values are interpolated to construct spatial modeling of meteorological drought levels. Through the LANDSAT satellite image, NDVI is calculated and built on a map of drought levels. Weighted overlay SPI and NDVI map layers for a drought risk map. Research results have shown that the Tien river estuary area is divided into 2 zones: light drought and moderate drought occurs in the dry season. Drought occurred with strong intensity in the eastern coastal area of Ben Tre and Tra Vinh provinces, the deeper the inland the level of drought decreased.

***Keywords***: drought index, NDVI, SPI, risk assessment, Tien river estuary.

## 1. Introduction

Drought together with climate change is one of the prominent global issues so many authors in the world have studied drought research. But this is inherently severe natural phenomena with high complexity, so far there is no general method to study the problems of drought. However, it is now common in the world for researchers to use drought indicators in their research. Among the meteorological indicators, since 1996 the group of authors Michael J. Hayes, Mark. D. Svoboda et al. [1] studied drought through the Standardized Precipitation Index (SPI). And then a series of other authors such as the study of drought climate in Europe by author Benjamin Lloyd-Hughes And Mark A. Saunders [2] (2002) also assessed drought based the SPI and the Palmer drought severity index (PDSI); or research by A. Loukas and L. Vasiliades [3] (2004) assessing the probability of Greek drought through SPI.

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Through research, up to now, developed countries in the world have been aiming at managing drought. Therefore, the application of remote sensing technology in research, evaluation, and drought management has been concerned by many researchers around the world. In 2006, Parul Chopra [4] researched of drought risk assessment by remote sensing technology and GIS through NDVI, SPI, and fluctuations in agricultural output chain applied to the specific case is the Gujarat area, India. Or the research of assessing the risk of drought using remote sensing and GIS technology: The case of the southern region of Tigray, Ethiopia by Birhanu Gedif et al [5] (2014) also used remote sensing technology Predicting image, calculating NDVI and Vegetation Condition Index (VCI) to establish and zoning drought risk map.

In Vietnam, in recent years, there have also been many authors applying remote sensing technology and GIS in drought research. In 2013, the author Le Thi Thu Hien [6] implemented the project "Application of plant index (NDVI) of Landsat image to assess the desertification of Binh Thuan province". Or as the study "Application of Remote Sensing to Assess Han Drought Risk in Bac Binh District, Binh Thuan Province" by Trinh Le Hung and Dao Khanh Hoai [7] presented the results of assessing the risk of drought in the area. Bac Binh district (Binh Thuan province) from LANDSAT multispectral satellite image data using plant temperature drought index (TVDI).

For the Mekong Delta region in general and the Tien River in particular, there have been many studies on drought in recent years. Example there is the research "Building meteorological forecasting technology in the Mekong Delta" by Nguyen Dang Tinh et al. [8]; or "Developing drought map of the Mekong Delta in the context of climate change" by author Tran Van Ty et al.; the research "Drought fluctuations in the dry season in Tien Giang province period 1980 - 2015" by Dao Ngoc Hung et al. [9]. However, these researches are mainly evaluated based on meteorological drought indicators, but there is no comprehensive evaluation of criteria belonging to different drought groups.

From the scientific researches on drought both at national and abroad, it can be seen that there are still some problems:

- There is not any index that stands out from the others. Therefore, the decision to select a drought indicator set will depend on the specific characteristics and conditions of each region as well as the available monitoring data.

- Studies on assessing drought risk combining two criteria in the group: using remote sensing image interpretation technology (NDVI) and meteorological term (SPI) for Tien river estuary are not available.

Therefore, the research project on drought risk in Tien river estuary using a combination of SPI and NDVI drought indicators is a practical and meaningful research.

## 2. Content

### 2.1. Materials and methods

#### 2.1.1. Study area

The Tien estuary area is in the latitude range from 9°31’46”N to 10º35’26”N, longitude from 105º49’07”W to 106º48’06”W, including administrative territories of three provinces: Tien Giang, Ben Tre, and Tra Vinh. Administratively, the area of the

Tien River belongs to the Mekong Delta region; naturally, this area is a part of the lower Mekong River. Tien river area is adjacent to 5 provinces/cities: Ho Chi Minh City, Long An, Dong Thap, Vinh Long, Soc Trang, has a total area of about 7263.3 $km^2$.

Although the Tien estuary area in the lower Mekong region has abundant river water, it varied to the area's additional humidity. But due to being located in the famous monsoon region in Southeast Asia, the weather here has two distinct seasons each year: the rainy season almost coincides with the summer, lasting from May to November (coming soon and ending later than the North). It is noteworthy that the activity and abnormality of the marine gas masses together with the activity of monsoon and the equator-tropical disturbances which govern and determine the temporal change weather conditions in this area, which have resulted in unusual natural varying, including drought.

**2.1.2. Data**

**** Meteorological Data***

Data on rainfall at meteorological stations in provinces of Tien river estuary (My Tho, Ba Tri, Cang Long) and nearby stations: Vung Tau, Moc Hoa, Cao Lanh, Tay Ninh, Can Tho, Soc Trang, period 1990 - 2018 provided by Vietnam Institute of Meteorology Hydrology and Climate change. Through this data series, calculate 1-month SPI, then select the months of generals corresponding to NDVI to develop a meteorological drought map of the Tien river estuary area.

**** Remote Sensing Data***

For the analysis of drought severity, the LANDSAT images (path 125 row 53) were obtained from the USGS website, with a spatial resolution of 30m for Apr 12, 1991; Feb 18, 2001; Feb 27, 2010, and Mar 19, 2018, respectively (Table 1).

***Table 1. Information on satellite image data used in research***

| No. of image | Satellite | Sensor | Band for calculating NDVI | Spatial resolution | Date of acquisition |
|---|---|---|---|---|---|
| 1 | LANDSAT 5 | TM | 3, 4 | 30 m | Apr 12, 1991 |
| 4 | LANDSAT 7 | ETM+ | 3, 4 | 30 m | Feb 18, 2001 |
| 5 | LANDSAT 5 | TM | 3, 4 | 30 m | Feb 27, 2010 |
| 8 | LANDSAT 8 | OLI | 4, 5 | 30 m | Mar 19, 2018 |

Meteorological data were used to calculate SPI. Remote sensing data were used to calculate NDVI. The interpolation method was used to visualize the spatial variability of SPI and NDVI in the study area. From there identify the drought severity areas. Drought risk maps are a weighted linear combination for all input factors in April 1991, February 2001, February 2010, March 2018. Interpolation method was used to visualize the droughts for April 1991, February 2001, February 2010, March 2018 separately. The final drought risk map was generated to visualize the spatial and temporal variation from the period 1991 - 2018 during the dry season in the study area.

### 2.1.3. Method

**** Assessing drought through NDVI***

Normalized Difference Vegetation Index (NDVI) quantifies vegetation by measuring the difference between near-infrared (which vegetation strongly reflects) and red light (which vegetation absorbs). NDVI always ranges from -1 to +1. But there isn't a distinct boundary for each type of land cover. For example, when you have negative values, it's highly likely that it's water. On the other hand, if you have a NDVI value close to +1, there's a high possibility that it's dense green leaves. NDVI uses the NIR and red channels in its formula [10]:

$$\mathrm{NDVI} = \frac{\mathrm{NIR}-\mathrm{RED}}{\mathrm{NIR}+\mathrm{RED}} \quad (1)$$

where NIR - reflection in the near-infrared spectrum; RED - reflection in the red range of the spectrum

In this study, the author used the satellite image LANDSAT to calculate NDVI for the times of April 1991, February 2001, February 2010, March 2018. NDVI values are categorized into five different (Table 1) classes based on the classification of NDVI results [10]. The classification of NDVI values are performed for the indication of vegetated and non-vegetated areas and is further used to assess dry and wet areas.

***Table 2. Classification of NDVI***

| NDVI ranges | Drought |
|---|---|
| ≥ 0.3 | No drought |
| 0.2 – 0.3 | Light drought |
| 0.1 – 0.2 | Moderate drought |
| 0 – 0.1 | Severe drought |
| < 0 | Very severe drought |

**** Meteorological drought assessment through SPI***

Meteorological drought is defined as a period with an abnormal precipitation deficit, concerning the long-term average conditions for a region. The SPI indicator shows the anomalies (deviations from the mean) of the observed total precipitation, for any given location and accumulation period of interest. Since SPI can be calculated over different precipitation accumulation periods (typically ranging from 1 to 48 months), the resulting different SPI indicators allow for estimating different potential impacts of a meteorological drought:

- SPI-1 to SPI-3: When SPI is computed for shorter accumulation periods (e.g., 1 to 3 months), it can be used as an indicator for immediate impacts such as reduced soil moisture, and flow in smaller creeks.

- SPI-3 to SPI-12 When SPI is computed for medium accumulation periods (e.g., 3 to 12 months), it can be used as an indicator for reduced streamflow and reservoir storage.

- SPI-12 to SPI-48: When SPI is computed for longer accumulation periods (e.g., 12 to 48 months), it can be used as an indicator for reduced reservoir and groundwater recharge.

Therefore, a month SPI was calculated for 9 rainfall stations using monthly rainfall data for the period of 1986-2018 by Drin C software. But only assess the months

corresponding to the NDVI. The category column in the drought severity classification table (Table 3) has been modified to suit the reclassification of the SPI maps.

***Table 3. Classification of SPI***

| SPI ranges | Drought |
|---|---|
| > 0 | No drought |
| 0 – -1.0 | Light drought |
| -1.0 – -1.5 | Moderate drought |
| -1.5 – -2.0 | Severe drought |
| ≤ -2.0 | Very severe drought |

*Source: (U.S. National Drought Mitigation Centre)*

**** Method of mapping maps and geographic information systems (GIS)***

In order to present a visualization of the data, the results of the study, the author has applied informatics software (excel and Drin C) to build visual charts.

In the process of creating drought maps based on NDVI and SPI, the topic also used Arcgis 10.5 software to interpret images, calculate NDVI, interpolate SPI, weighted overlay.

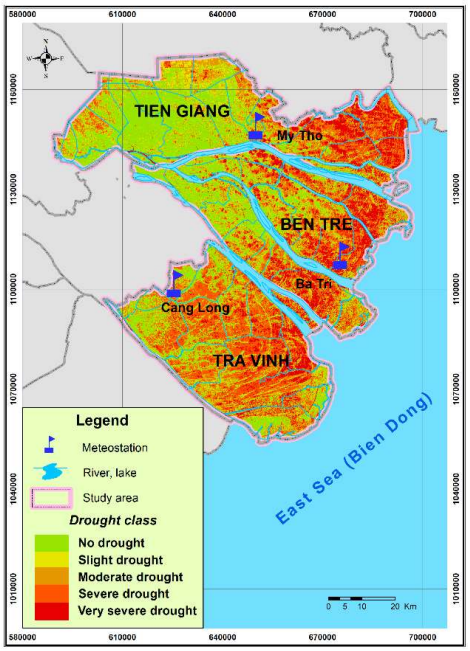
The map of drought risk the Tien river estuary area was calculated by the method of weighted overlay linear maps for 1991, 2001, 2010 and 2018. Points are assigned to values 1 - 5 respectively with the level from very severe to no drought, for this research, the author chose an average rating so the weight for the SPI and NDVI classes is 0.5 - 0.5. The aggregate score from the linear weighting map model is reclassified into 5 levels of drought respectively as no drought, light drought, moderate drought, severe drought, and very severe drought.

## 2.2. Results and discussion

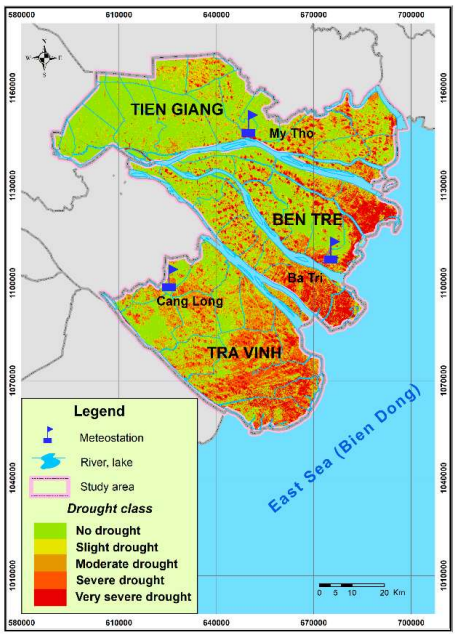
**** NDVI and drought***

NDVI for the years 1991, 2001, 2010, and 2018 was calculated using ArcMap 10.5. On the basis of this NDVI, drought classes were derived and the trend in their shift was also identified.

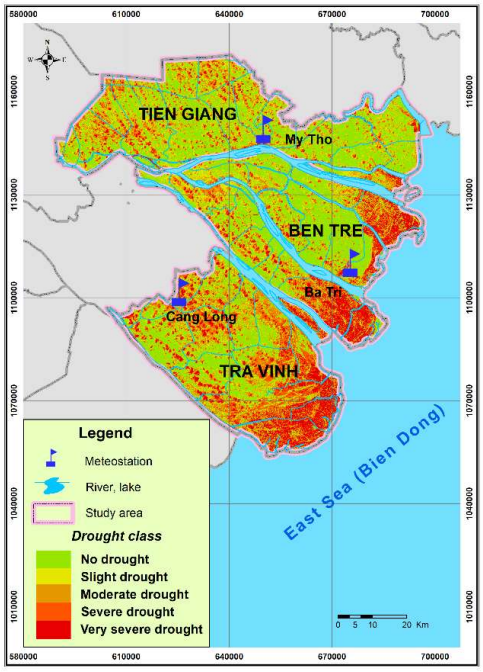
Analysis of the maps in Figure 1 shows that during the dry season, the drought in Tien river estuary area tends to decrease. However, until 2018 in the study area, still there were enough to 5 drought levels: from no drought to very severe drought. Through this, it is also possible to see that the area frequently affected by drought is the coastal area in the east and southeast. These areas in the dry season often occur saline intrusion, making the impact of drought even more severe.



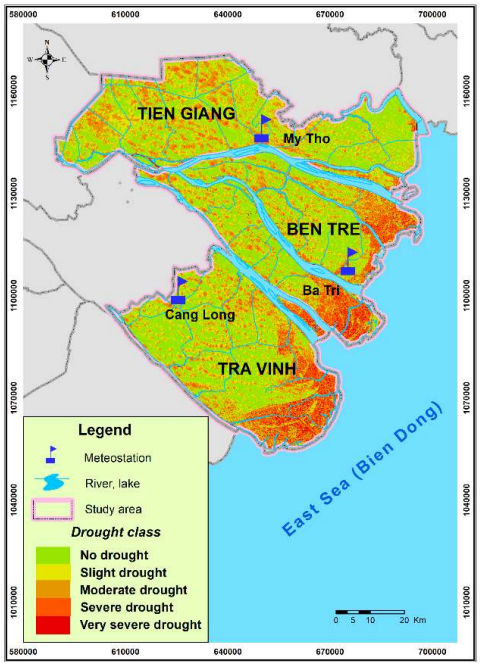

*a) Apr 12, 1991*




*b) Feb 18, 2001*




*c) Feb 27, 2010*




*d) Mar 19, 2018*

***Figure 1. Drought map of Tien river estuary area based on NDVI***

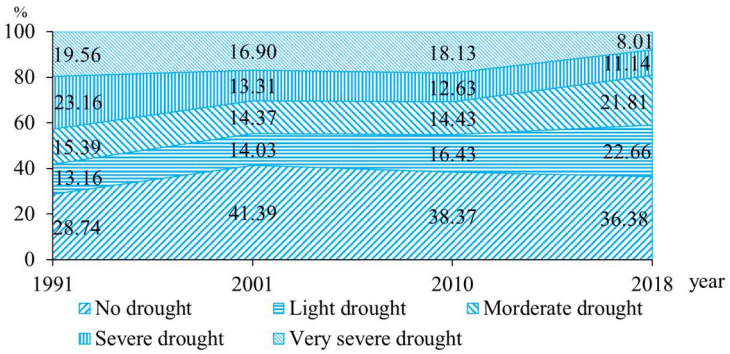



***Figure 2. The diagram shows the area structure of the drought class in the Tien river estuary over the years***

Based on Figure 2, the drought trend of the Tien estuary area is even more apparent. Although in 2001, the total area of drought levels decreased compared to 1991 but since then the total area of drought levels has tended to increase. By 2018, the percentage of the area without drought will be reduced to 36.37%; severe and very severe drought levels have decreased but the total ratio of light and moderate drought areas has increased to 44.5% of the total area of the region.

**** SPI and drought***

Drought risk was identified using SPI values over 28 years. SPI during selected months of April 1991, February 2001, February 2010, March 2018 has been presented to show the pattern of SPI during these years as other relevant data was only for these years.

Calculated a month SPI values for the months of April 1991, February 2001, February 2010, March 2018 at the mathematical stations show the level of fictional drought in the study area. Except for 2001, SPI values of stations are very low, ranging from 0.63 to -1, which shows that the risk of drought in the Tien river estuary area is very high. My Tho station always has a low SPI value below 0.5. Ba Tri station in 2010 and 2018 was also below 0.5. Cang Long station in 2018 increased slightly compared to 2010 but still has not surpassed the level 1. Thus, it can be seen that the general trend of the Tien river estuary area is worth 1 month - SPI is declining, the risk of meteorological drought is very high.

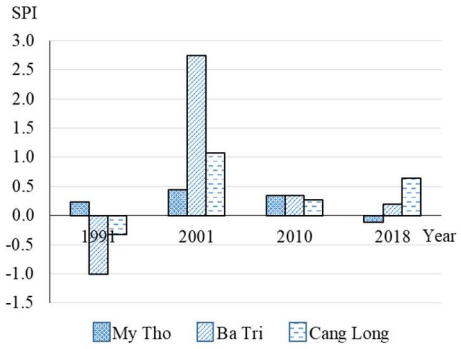
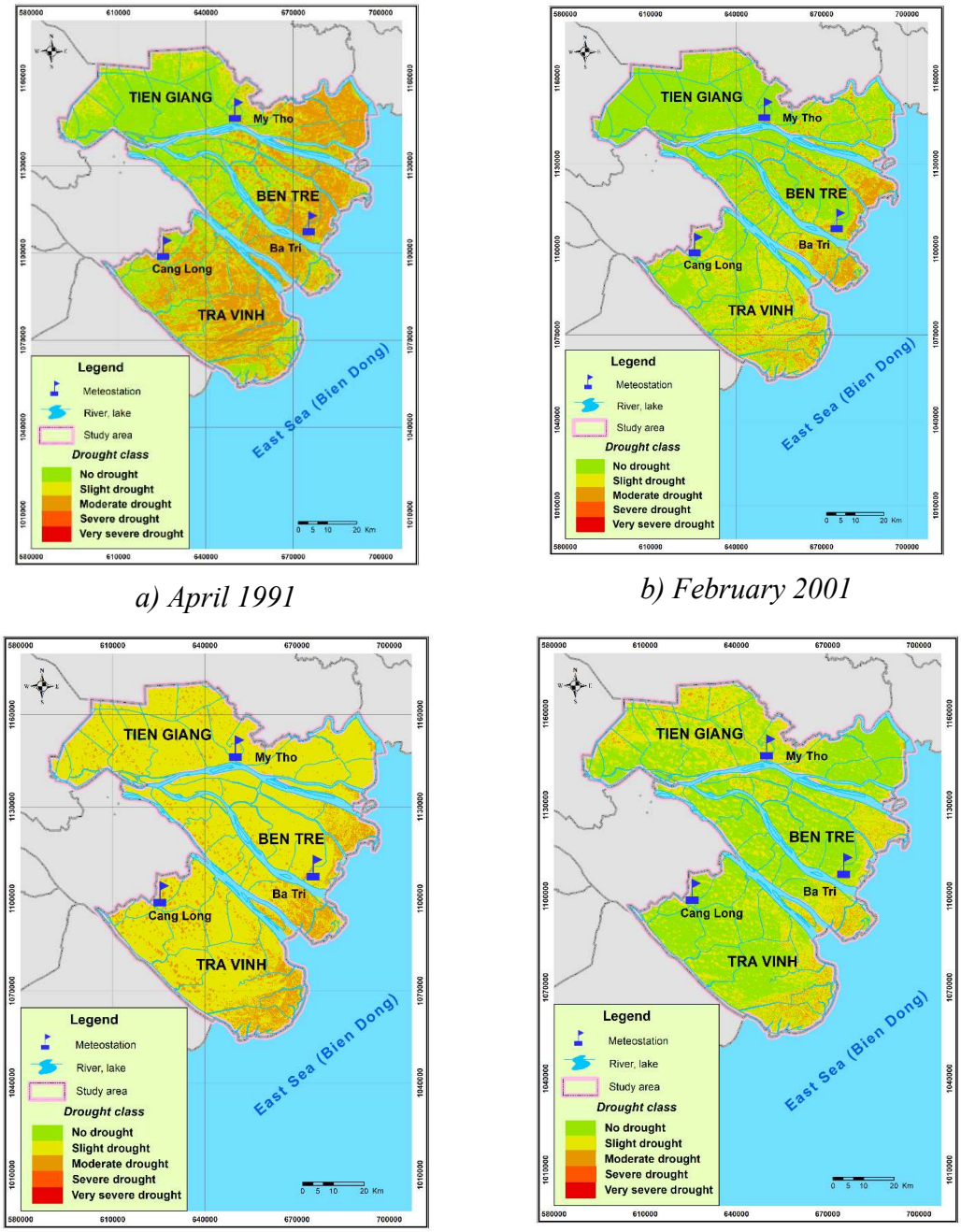



***Figure 3. The diagram shows of SPI values at meteorological stations in the Tien River estuary area***

**** Drought risk***




*a) April 1991*

*b) February 2001*

*c) February 2010*

*d) March 2018*

***Figure 4. Map of drought risk of Tien river estuary area***

Drought risk was assessed using NDVI and SPI values by linear combination weighted system. Both NDVI and SPI for all four years were separately reclassified and weights were assigned to the classes. The weights were assigned to each class in the range of 1-5. To the lowest value of the SPI and NDVI weight of 1 was assigned. Then, drought severity was assessed for the months of April 1991, February 2001, February 2010, March 198

2018. And the result of the evaluation is that the Tien river estuary area only 3 zones exist including 'No drought', 'slight drought' and 'moderate drought'. Figures 4 (a, b, c, d) show the distribution of these classes for the months April 1991, February 2001, February 2010, March 2018. These images clearly give a scenario of drought prevalence and its trend in the area. From 1991 - 2018, during the dry season, the area of moderate drought areas decreased. But in 2010, the entire region experienced drought from light to moderate drought. The drought characteristics of Tien river mouth are mainly in coastal areas, the deeper inland the drought severity decreases, especially in coastal areas of Tra Vinh and Ben Tre provinces.

## 3. Conclusions

Under the impact of climate change, weather patterns are varied changing, the drought situation in the Tien river estuary area is increasingly complicated due to lack of rainfall and increasingly scarce water resources. From this study, it can be concluded as follows:

- The combination of the SPI index and NDVI to assess drought risk in the Tien river estuary area shows the synthesis and increase the accuracy, close to the reality of the research results.

- In the area of Tien river estuary, drought is more serious in coastal areas, the deeper inland, the more severe the level of drought is reduced.

- Up to 2018, during the dry season of Tien river estuary area, there is only slight and moderate drought.

- Of the 3 provinces in the Tien estuary area, drought is strong in the coastal areas of Ben Tre and Tra Vinh provinces.

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