DEVELOPMENT AND APPLICATION OF SATELLITE-BASED AGRO-METEOROLOGICAL DROUGHT INDEX (SAMDI)

Ye-Seul Yun (1), Yang-Won Lee (2)

[1] Pukyung National Univ., 45 Yongso-ro, Nam-gu, Busan, 48513, Korea
[2] Pukyung National Univ., 45 Yongso-ro, Nam-gu, Busan, 48513, Korea
Email: yeah519@gmail.com; modconfi@pknu.ac.kr

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ABSTRACT: Drought is natural disaster caused by long-term lack of water. Unlike other natural disasters, it is difficult to accurately determine the start and end, and when it occur, the socio-economic losses are high. Because the range or extent of the damage caused by the drought varies, the definition also varies. Drought can be characterized into four perspectives. 1) Meteorological drought, when rainfall is below the normal year value, 2) Agricultural drought, which affects crops due to lack of soil moisture, 3) Hydrological drought, which affects by the amount of available water resources such as streamflow and reservoirs, 4) socio-economic drought, which considers regional environmental and economic impacts. Drought cannot use traditional assessment and forecasting methods. So, we use drought index to know quantification of drought. Numerous drought indices are being developed, and they are selected by the drought conditions and the strengths and weaknesses of each index. Because they are difficult to monitor continuously over large areas that indices using the point-based station data, Drought indices using satellite-based data are widely used such as The Normalized Difference Vegetation Index (NDVI), The Normalized Difference Water Index (NDWI), The standardized precipitation index (SPI), and The vegetation health index (VHI). Generally, if when meteorological drought gets worse, it follows agricultural drought, and if when agricultural drought gets worse, if follows the next turn. But, in the case of the Korean peninsula in 2018, due to short-term high temperature hear, agricultural drought immediately occurred without going through meteorological drought. So we needed a new index to express this event. This process is similar to the process of calculating the SPI which is widely used as the meteorological drought index. However, in this study, this process was further developed and, the precipitation (P) and actual evapotranspiration (ET) were used to symbolize the supply and consumption of water according to the "water balance" perspective. This satellite-based agro-meteorological drought index (SAMDI) can be used to monitor drought event that are difficult to monitor due to the drought index that used only precipitation data, and we expect to be able to quickly monitor agriculture drought.

1. INTRODUCTION

Drought is a natural disaster caused by long periods of water shortage. Unlike other natural disasters, it is difficult to judge the beginning and the end correctly, and if so, economic and social losses are large (Wilhite, 2000). The definition of drought is different because of the different parts and extent of damage caused by drought. drought can be classified into four categories: 1) meteorological drought, when precipitation is less than average, 2) agricultural drought, which affects crops due to lack of soil moisture, 3) Hydrological drought, which defined by amount of available water resources such as the river flows and reservoirs in the country, and 4) socioeconomic droughts that take into account the local environmental and economic impacts.

Because droughts cannot use traditional methods of assessment and forecasting, they use the drought index to quantify droughts. Numerous drought indices are being developed, and various types of drought indices are selected according to drought conditions and strengths and weaknesses. Since indices using point-data are difficult to continuously monitor over large areas, drought indices using satellite-based data are frequently used. For example, NDVI and NDWI are widely used for vegetation monitoring, SPI which can express water deficit only by precipitation, and VHI which expresses vegetation health status.

In previous research, precipitation shows significant contributions to determining the onset, duration, intensity, and end of the drought, but studies have shown a lack of drought index using only precipitation. Indices representing drought should also take into account other variables that may affect the drought, such as temperature, evapotranspiration, wind speed, and soil holding capacity, to reflect both extreme weather and additional environmental impacts (Heim,2002; Vicente-Serrano,2010).

2. STUDY AREA

The study area is South Korea, focusing on cropland, but the scope of agriculture and forest combined with cropland, and forest to observe the overall pattern change. Since vegetation growth may not be observed normally in winter, the study period was set from March to November except winter. It is from 2001 to 2018 in accordance with the timing of the provision of satellite data.

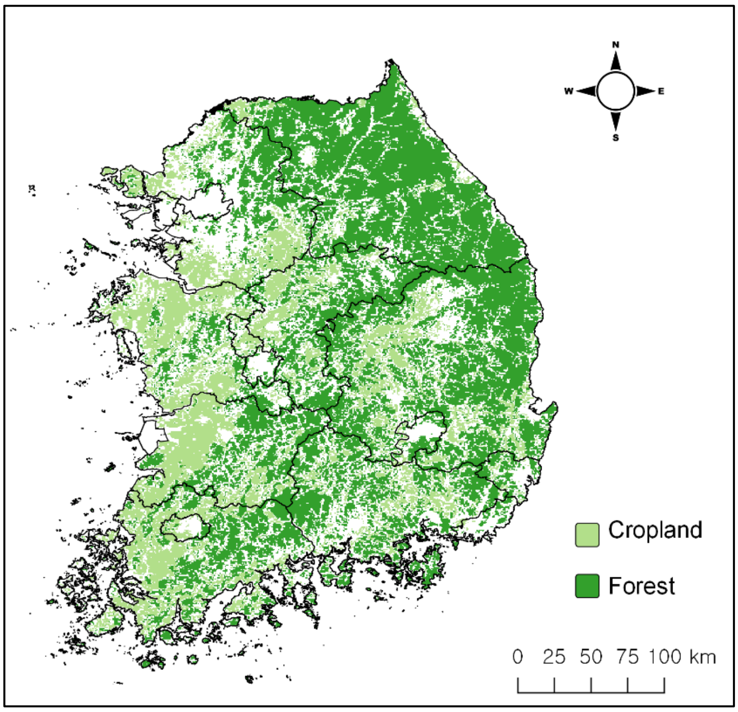


Figure 1. Distribution of croplands and Forest from MODIS land cover data in South Korea.

3. OBJECTIVES

Generally, severe meteorological-droughts lead to agricultural-droughts and severe agricultural-droughts lead to hydrological droughts. These events can be divided into two types: the first is a typical type of drought, in which meteorological-drought caused by lack of precipitation leads to agricultural drought, and second is drought caused by climate change and anomalous weather, in which agricultural-drought occurs due to extreme heat and excessive evapotranspiration, not meteorological-drought. In South Korea in 2018, however, short-term heat waves caused agricultural droughts without immediate meteorological-drought.

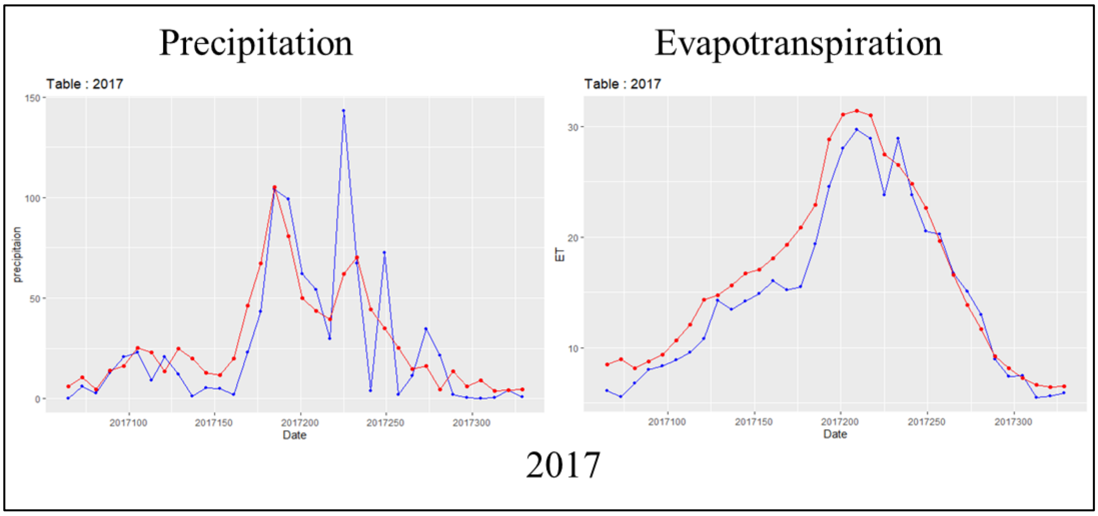


Figure 2. The red line represents the normal year's precipitation (P) and evapotranspiration (ET), and the blue line represents P and ET in 2017.

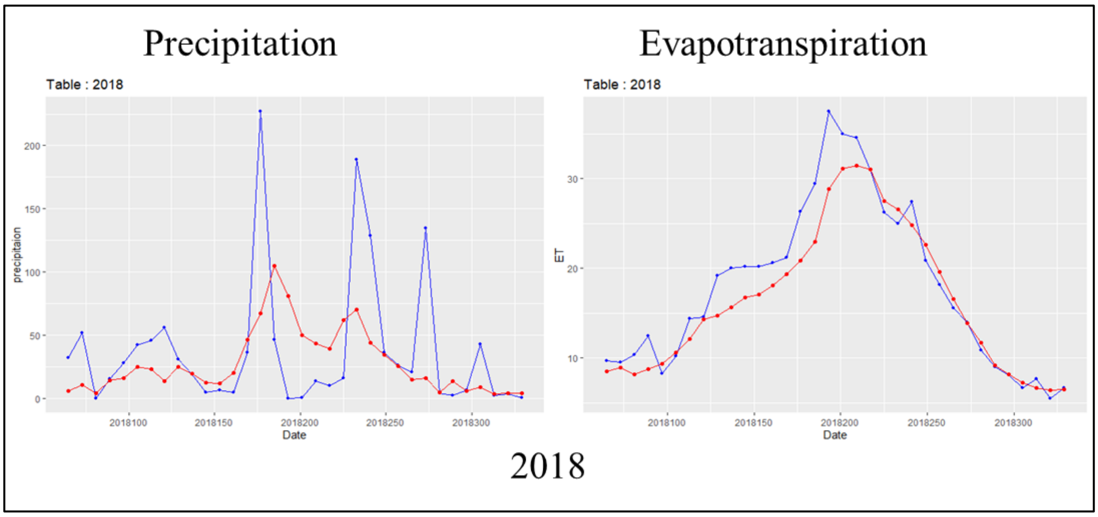


Figure 3. The red line represents the normal year's precipitation (P) and evapotranspiration (ET), and the blue line represents P and ET in 2018.

As shown in Figure 2 and 3, the 2017 model continues to have fewer rainfall and evapotranspiration conditions than normal year, but 2018 has more rainfall and overall evapotranspiration than usual.

4. METHODOLOGY

In this study, according to the "water balance" point of view, precipitation (P), symbolizing the supply of water, and potential evapotranspiration (PET), representing the consumption of water, were used. This process is similar to the calculation process of SPI or SPEI which is widely used as weather drought index.

4.1 Data Collection

For land cover data, Type 1 (IGBP) of MODIS land cover (MCD12Q1) was used. Class 1 ~ 5 marked Forest was designated as ‘Forest’ and Class 12 and 14 designated Cropland were designated ‘Cropland’. Satellite data were used the MODIS Terra, TRMM, the data in the 1km and 8-day interval was resampled according to the resolution of the MODIS.

Table 1. Summary of data used.

Data		Temporal resolution	Spatial resolution
TRMM	Precipitation	1-day	0.25°
MODIS Terra	PET	8-day	1km

4.2 Data Processing

Satellite-based agro-meteorological drought index (SAMDI) tried to solve the problem of overestimation of drought in existing SPEI. The existing SPEI method had to treat the same case for:

1) Low rainfall and low evapotranspiration.
2) High rainfall and high evapotranspiration.

However, if the sum and difference are used together as in the following equation, the state difference for 1) and 2) can be distinguished.

Basically, SPEI makes D, which is the difference (D) between P-PET, and accumulates to about 1, 2, 3... 6 months as time passes. Using the accumulated D, indicate how many values were less than the average year.

$$\boldsymbol{D = P - PET} \qquad \textbf{(a)}$$

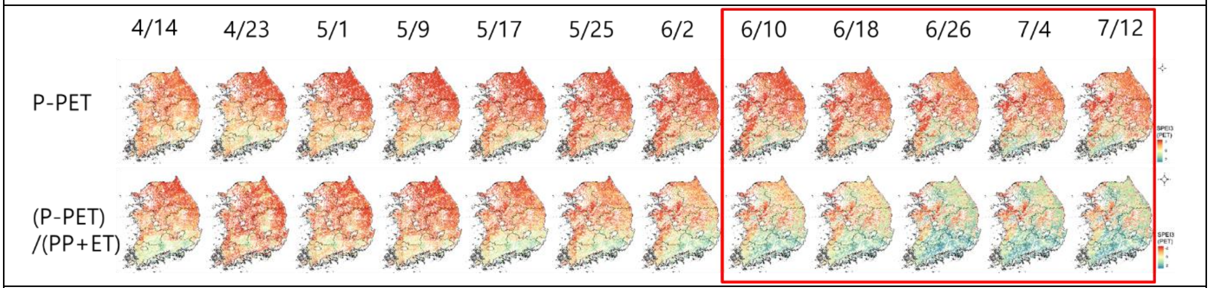
$$\boldsymbol{D = (P - PET)/(P + PET)} \qquad \textbf{(b)}$$

In this study, we made a modified D with this method, and then produced a commonly 3-month cumulative value. The values were put into Empirical cumulative distribution function (ECDF) using D accumulated for 3 months and then normalized using the mean and standard deviation. In the above formula, (a) is the conventional D and (b) is the D used in this study.

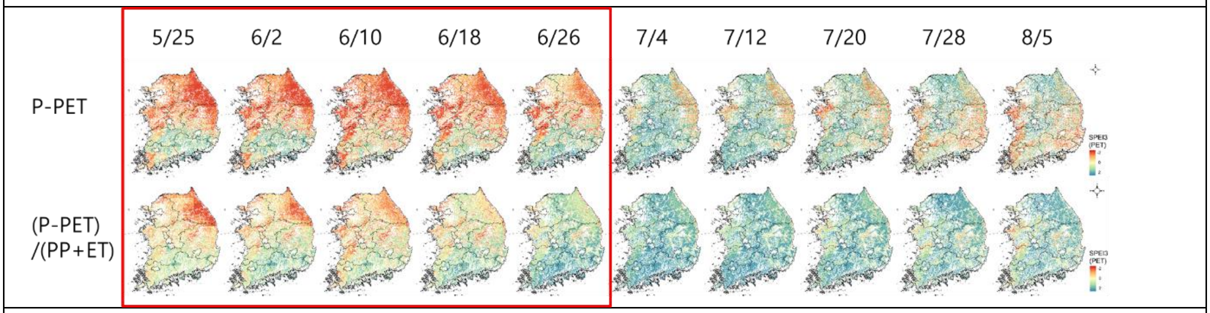
5. RESULTS

Table 2. Compared with map each years (2015~2018).

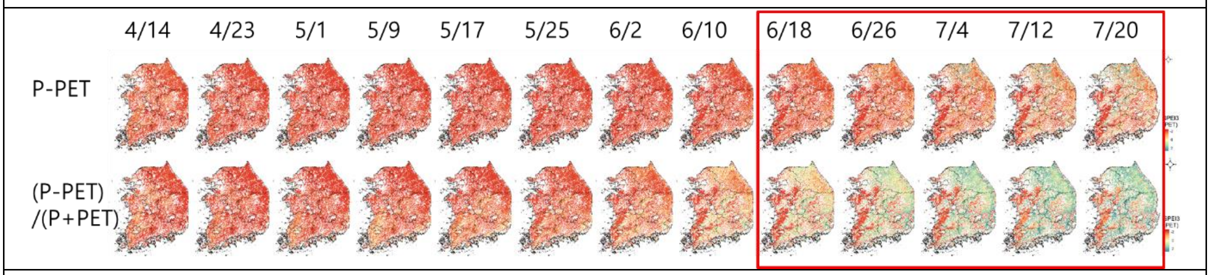
Year of 2015



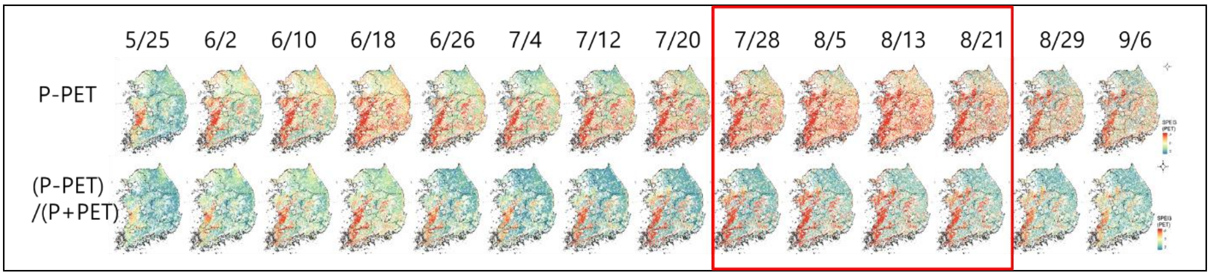
Year of 2016



Year of 2017



Year of 2018



In the table, we are mapping each year's indices. Year of 2015 and 2017 were typical years of low rainfall and low evapotranspiration. The existing method of SPEI shows little precipitation between mid-June and mid-July, but it is not well in relieved from drought. Year of 2016 can be seen as a period of no-drought because of the summer precipitation, and SPEI's approach indicates that this period is also drought, while SAMDI's approach well represents the period of drought. In 2018, the early rainy season ended early July, with little precipitation until the end of August. And it was a year when excessive evapotranspiration occurred due to the extreme heatwave. Although approach of both SPEI and SAMDI reflected evapotranspiration well, but SAMDI's method represented a concentrated damage zone.

6. CONCLUTION

This satellite-based agricultural drought index (SAMDI) calculates drought events, which are difficult to confirm only by precipitation data due to climate change, by adding an evapotranspiration. This is expected to be used to monitor drought events where meteorological droughts do not occur due to excessive evapotranspiration, such as the 2018 drought. And It is also expected that this index will be able to quickly identify the damage zones that crops are being damaged, so that agricultural droughts can be monitored quickly. In addition, further research will be carried out through meteorological factors and reanalysis data.

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