Evaluating drought indices for agricultural drought monitoring in Gia Lai province, Vietnam

Chu Minh Thu and Michiaki Sugita
University of Tsukuba, Ibaraki, Japan

1. Introduction

Gia Lai province is located in the Central Highlands which is a major cultivation area of coffee in Vietnam. However, the Central Highlands is exposed to regular drought. In recently years (1989 – 2006), there were 15 droughts in this area (Nguyen, 2014), especially during the drought in 1998 drought-prone coffee area was 74,400 ha and 770,000 persons were a lack of water (Dao, 2005). Hence, understanding the characteristics of drought will help to mitigate the adverse effects of drought on agriculture. Wilhite and Glantz (1985) classified drought into four types: meteorological, agricultural, hydrological, and socio-economical. This study focuses on agricultural drought, which is basically identified by the moisture deficit that leads to reductions of cultivation production. Agricultural drought can be characterized by drought indices (Sivakumar et al., 2010; Liu et al., 2016). Some indices are commonly applied in monitoring, early warning in drought-prone regions. Unfortunately, no particular drought index would be suitable to represent the drought conditions for all regions due to the differences in climatic conditions, soils, and crops. In addition, according to the definition, crop yield could be a good indicator for evaluating the indices in term of monitoring agricultural drought. Therefore, this study aims to find out the appropriate index for monitoring agricultural drought by examining the temporal relationship between the drought indices and some crop yields in Gia Lai province.

2. Methods and materials

Thirty-four indices are commonly used for monitoring and early warning in drought-prone regions around the world (Sivakumar et al., 2010). In this study, two indices were considered. They are Standardized Precipitation Index (SPI) (McKee et al., 1993), and Crop Drought Index (CDI) (Łabędzki & Bąk, 2014). SPI is a precipitation-based index, which is recommended by WMO and widely used to monitor the drought phenomena. CDI is an index calculated by the reduction of evapotranspiration in relation to potential evapotranspiration. These indices were computed at time steps of 1 month, 6-month (Dec to May) and 12-month (Jan to Dec). The two indices were examined with two major crops in Gia Lai province: spring rice paddy (largely grown in the southeast part of Gia Lai province) and coffee trees (mainly grown in the northwest part). Crop yield residual (CYR) was used for eliminating the effect of farming technology improvement on the growth of crop yield. CYRs were calculated as departures of crop yield from its trend. Then the correlation between the two indices and the CYRs were determined and examined.

3. Results and discussion

The results show that CYRs (rice paddy and coffee) exhibit extreme reduction over the 2002 – 2005 period which indicates the period of severe drought (Dao, 2005). The temporal variation of the two indices indicates that both SPI and CDI estimated for the growing season were able to capture this signature (Fig.1). Especially, CDI shows the better performance than SPI as it successfully captured the two extreme reductions of CYR in 2002 and 2005. The coefficient of determination ($R^2$) between growing season SPI and annual CYR is 0.1 for spring paddy rice and 0.001 for coffee while this value of CDI is much higher, 0.56 and 0.62, respectively.

Figure 2 shows the result of a correlation analysis in which the value of $R^2$ was determined for the pair of monthly CDI or SPI and annual CYR values for the 2000-2010 period. CDI exhibits the strongest relationship with CYR for the higher value of the coefficient of determination and for the period of time when the coefficient is higher than 0.4 (p<0.05). The results also prove that CDI in the mid-season can be used to detect agricultural drought in the study area due to the highest relationship with CYR.
a) Spring paddy rice  

b) Coffee

Figure 1 Comparison between annual CYR with SPI and CDI (for the growing season, a) 6 months (Dec – May) for spring paddy rice and b) 12 months (Jan – Dec) for coffee during the period 2000 - 2010.

Figure 2 Coefficient of determination between 1-month indices and corresponding annual crop yield for a) spring paddy rice and b) coffee.

4. Conclusions

There was a significant correlation between CDI and CYR of spring paddy rice and coffee; however, the strength of the correlation varied by period for which CDI was determined. This can be explained by the fact that the reduction of crop yield depends not only on the severity of droughts but also on the onset time and duration of droughts. It has been found that drought in the mid stages of crop growth period has more impact on crop yield reduction. Therefore, CDI values in February and April can be used for early predicting of crop yield. The differences in the correlation between the two indices with CYR indicates the needs to test other indices to find out the most appropriate index for agricultural drought monitoring in Gia Lai province.

References

Keywords: drought indices, agricultural drought, Standardized Precipitation Index, Crop Drought Index