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Short Communication

Comparison of drought indices (SPI and RDI) over Mekong Delta area of Vietnam

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Vietnam has witnessed several droughts over 90 years of which 2014-2016 was a worst drought event with 83 per cent of affected area (FAO 2014). Recognizing the importance of drought, numerous studies on drought events at global, regional and national scales are receiving a lot of interest from researchers around the world(Bayissa *et al.* 2018). McKee *et al.*(1993) proposed meteorological drought to be defined in terms of the magnitude of a rainfall shortfall and the duration of this shortfall event. The standardized precipitation index (SPI) was, therefore, developed for predicting meteorological drought and has been successfully applied in many regions in the world (Bateni *et al.* 2018).One of the advantages of the SPI is that it can be used for different time scales and input data only required precipitation. Another index viz. the reconnaissance drought index (RDI) is also used to define meteorological drought and is very sensitive to drought events (Bayissa *et al.* 2018).

Khalili *et al.* (2011) analyzed the SPI and RDI meteorological drought indices in different climatic zones of Iran. The results revealed that the RDI is very sensitive to climatic variability if the drought analyses are to apply for agricultural applications, utilization of the RDI would seem to serve a better purpose.Rahmat *et al.* (2015) used the SPI to estimate meteorological droughts in Australia and showed that the application of the SPI was carried out to be satisfactory for assessing and monitoring meteorological droughts. Lee and Dang (2018) used SPI to analyse drought associated with El-nino events in Vietnam, while Pradhan *et al.* (2011) used SPI for meteorological drought analysis for New Delhi, India.

The Mekong Delta area situated in southern of Vietnam, is dominated by monsoon circulation namely northeast and southwest. The northeast monsoon (November to April) is characterized by dry and a very little rainfall while southwest monsoon (May to October) is characterized by humid and heavy rainfall (Vu *et al.* 2018). The climate brings its own nuances, which is high temperature and less variation (26.5-28.7°C) between months of the year with annual mean rainfall approximately 1700 mm. The present study was undertaken to analyse the drought characteristic of Mekong Delta using SPI and RDI indices.

Rainfall data series of 46 gauge-stations were collected from the Southern Regional Hydro-meteorological Centre of Vietnam (SRHCV), representing for 13 provinces of Mekong Delta area.However, based on the length of recorded data series minimum 31 years and missing data only twelve rainfall gauge stations were finally selected to analysis, assemble and detect drought events.

The SPI was calculated as described below, in which the cumulative probability distribution function is defined as the distribution of rainfall in the observation data series. The gamma probability distribution function g(x) is defined as

$$g(x) = \frac{x^{\alpha-1} e^{-x/\beta}}{\beta^{\alpha}\,\Gamma(\alpha)} \; ; (x > 0)$$

where β is a scale parameter, α is a shape parameter, x is the precipitation amount and $\Gamma(\alpha)$ is the gamma function.

The cumulative distribution function G(x) is obtained by

$$G(x) = \int_0^x g(x)\,d = \int_0^x \frac{x^{\hat{\alpha}-1} e^{-x/\hat{\beta}}}{\hat{\beta}^{\hat{\alpha}}\,\Gamma(\hat{\alpha})} dx$$

Where the parameter $\hat{\alpha}$, $\hat{\beta}$ are calculated by

$$\hat{\alpha} = \frac{1}{4A}\left(1 + \sqrt{1 + \frac{4A}{3}}\right)$$

$$\hat{\beta} = \frac{\hat{x}}{\hat{\alpha}}$$

$$A = \ln(\bar{x}) - \frac{\sum \ln(x)}{n}$$

n is number of precipitation observations and $\bar{x}$ refers to the sample mean of the data series. While the SPI dimension less function is defined by

$$SPI = \Psi^{-1}[G(x)]$$

A positive value of the SPI implies that rainfall at a particular region is higher average rainfall value while a negative value is the opposite. A region will be evaluated as drought if the SPI reaches a valueof -1.0 or less (Table 1).

The RDI is calculated using rainfall and potential evapotranspiration data series.

$$\alpha_k = \frac{\sum_{j=1}^{j=k} P_j}{\sum_{j=1}^{j=k} PET_j}$$

where P_j and PET_j are the rainfall and potential evapotranspirationof every month of the year.

In addition, the RDI can be defined as normalized (RDI_n) and standardized (RDI_{St}). Where the RDI_{st} is defined.

$$RDI_{St}(k) = \frac{Z_k - \bar{Z}_k}{St_k}$$

Where Z_k is ln(dk), $\bar{Z}_k$ is its arithmetic average and St_k is its standard deviation

The RDI_{St} is defined by a similar way with SPI and its values also compared to the same scale as the SPI (Table 1). Where a region is also considered as the occurred drought if the RDI_{St} value approaches -1.0 or less (Khalili *et al*. 2011). The Penman Monteith method was used to calculate reference evapotranspiration (ETo), which is assumed as PET.

The SPI and RDI indices were computed for all the stations (Table 2) for 31 years record (1984-2014) to estimate drought characteristics at 3-, 6-, 9- and 12-month time scales.However, for simplicity of presentation on comparing of SPI and RDI only two stations are selected the number of the occurred drought events at Chau Doc and Rach Gia stations for 3-, 6-, 9- and 12-month time scale during the study period are presented Fig.1.

Table 1: Classification scale for SPI and RDI values

SPI values	RDI values	Category
0 < SPI	0 < RDI	No drought
-1.0 < SPI≤ 0	-1.0 < RDI≤ 0	Mild normal
-l.5 < SPI≤ -l.0	-l.5 < RDI≤ -l.0	Moderate drought
-2.0< SPI≤ -l.5	-2.0<RDI≤ -l.5	Severe drought
SPI≤ -2.0	RDI≤ -2.0	Extreme drought

At Chau Doc station, for 3-month time scale using the SPI, ten moderates, five severe drought events and four additional extreme drought events with risk peak value of -2.81 in the year 2015 were recorded while ten moderate, six severe and three extreme drought events with risk peak of -2.77 in the year 2015 using RDI.At Rach Gia station,using for SPI, nineteen moderates, fourteen severe and three extremes drought events were recorded while with RDI, only eleven moderate, six severe and an extreme drought was recorded in the years 2013 with risk peak of -2.26.

For SPI 6-month time scale, Chau Doc station recorded six moderate, five severe drought events and three additional extreme drought events with the peak value of -2.86 recorded in 2015 while with RDI six moderate, four severe and four extreme drought events with risk peak of -2.90 in the year 2015 were recorded. Rach Gia station recorded seven moderate, four severe drought events and two extreme drought events with peak risk of SPI value -2.42 in 2005 while RDI recorded six moderate, five severe and two extreme drought events with risk peak value -2.37 in the same year.

For SPI 9-month time scale, Chau Doc station recorded three moderate and severe drought events and four extreme drought events with peak value of -2.93 in 2002 while RDI recorded three moderate drought events, two severe drought events and four extreme drought events in the years 2002, 2003, 2010 and 2015 with peak risk of -2.67.For Rach Gia station, the SPI and RDI indices carried out a similar way in detecting years of drought. Specifically, both the SPI and RDI indices found six moderate and severe drought events and an extreme event.

Similarly, the SPI and RDI indices 12-month drought scale, showed four moderate and severe drought events, and three extreme drought events at Chau Doc station were detected by SPI while five moderate drought events, three severe and extreme drought events were detected by RDI. For Rach Gia station, eight moderate, five severe and two extreme drought events were detected by the SPI while a similar result was also detected with RDI index (Fig. 1).

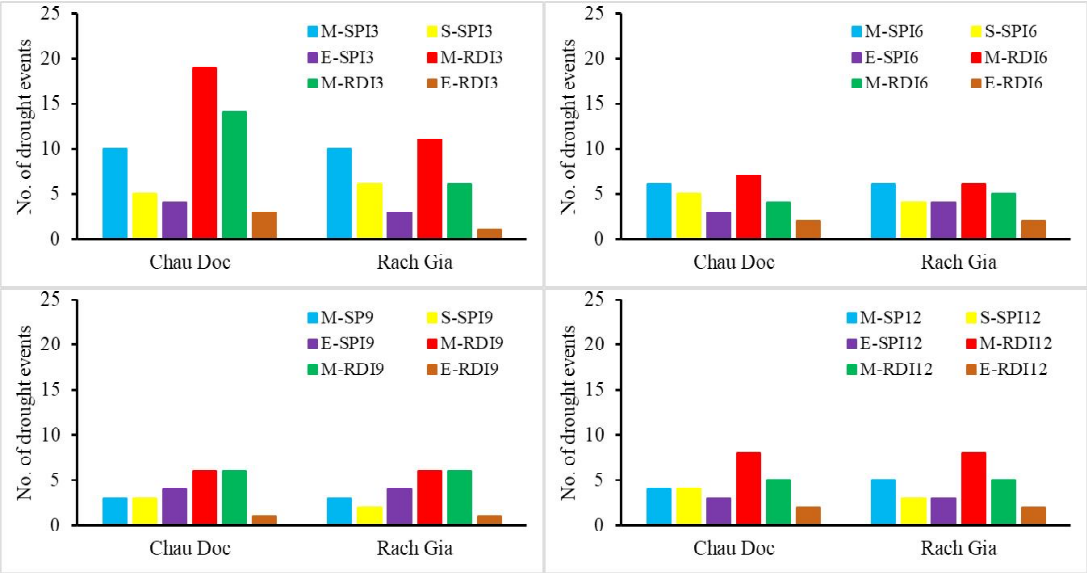

Fig.1: Drought events at 3-, 6-, 9-, and 12-month time scale using the SPI and RDI indices

Table 2: Correlation coefficient between the SPI and RDI indices for all time scales

Stations	Drought time scales			
	3-months	6-months	9-months	12-months
AnGiang	0.683	0.791	0.839	0.957
Can Tho	0.691	0.764	0.847	0.946
HauGiang	0.679	0.772	0.855	0.948
Tien Giang	0.686	0.749	0.849	0.977
Vinh Long	0.697	0.766	0.861	0.939
Soc Trang	0.738	0.809	0.868	0.968
Bac Lieu	0.725	0.799	0.877	0.982
KienGiang	0.745	0.811	0.883	0.979
Ca Mau	0.755	0.816	0.897	0.988
TraVinh	0.736	0.796	0.861	0.976
Ben Tre	0.722	0.791	0.875	0.968
Long An	0.694	0.773	0.834	0.945

As discussed above, the SPI and RDI indices identified almost the number of drought events during each drought stage with slightly different for 3-, 6- and 9- month time scales. Overall, the correlation between the SPI and RDI indices at all stations over the entire study area were found to be satisfactory. However, the lowest correlation coefficient values ranging from 0.683 to 0.755 were obtained for 3-month time scale while for 6- and 9-drought time scales the values of the correlation coefficient varied from 0.749 to 0.877 and the highest coefficient found for 12-month time scale (Table 2). Generally, the correlation increased with an increase in time scale and the main reason can be explained by the variability of the rainfall data when longer time scales were applied.

For the 12-month time scale, the detected drought events for all stations in the study area show that the drought events were slightly different about the number of drought events and its severity from one station to the other. The eastern coastal provinces recorded more drought events of 12-month time scale than the other provinces. One of the major causes is due to the inûence of the local conditions and the difference in rainfall for each location.

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