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Research Paper

A STUDY ON DROUGHT IN THE SOUTH-CENTRAL REGION: DETECTION FROM THE OBSERVATION AND THE BIAS-CORRECTION RAINFALL PROJECTIONS OF NATIONAL CLIMATE CHANGE SCENARIOS

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ARTICLE HISTORY

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ABSTRACT

This article presents the results of detecting the trend of drought conditions in the South-Central region based on the past observation and bias-correction rainfall projections. The past observation of daily rainfall is updated up to 2017 and collected from Vietnam Meteorological and Hydrological Administration. The bias-correction daily rainfall projections are collected from Vietnam Institute of Meteorology, Hydrology and Climate change (IMHEN) during the periods of 1986 - 2005, 2016 - 2035, 2036 - 2065 and 2080 - 2099 according to both RCP4.5 and RCP8.5 scenarios. The Standardized Precipitation Index (SPI) and minimum value of SPI (SPI_min) are used to define the mean drought condition and the most extreme drought condition. The past trend of drought conditions is found that the decreasing trends of mean drought condition and increasing trends of the severity level. The future trend of drought conditions according to both RCP4.5 and RCP8.5 is found that it is similar to the past trend. Where, the mean drought condition is generally found by slight decreasing trends. However, the most extreme of drought condition is significantly found by increasing trends of drought at shorter timescales (1- and 3-month time scales).

Keywords: *Drought condition, extreme drought, SPI, SPI_min, South-Central region.*

1. Introduction

Comparing with other climatic regions, the South - Central region has lowest dry seasonal rainfall. The dry season in the South-Central is longer than in other regions that mostly ranged from December (in the previous year) to August (in the next year). The climatology peak of the dry season is from January to March. Especially, the dry/drought condition in the South-Central region is known as having the strongest intensity in Vietnam (Ngu and Hieu, 2004).

As above mentioned, the dry/drought condition extremely has impacted on socio-economic sectors, environment and human life. Thus, many studies were focused on the dry/drought condition in the South- Central region. Thang et al. (2007) showed the very extreme drought events that ever occurred during 1980 - 2005 in the South - Central region as listed in 1983, 1993 and 1998. Where, extreme winter - spring drought events occurred in 1983, 1993, 1998 and summer - autumn drought in 1982, 1985, 1988, 1993 and 1998. Especially, the very extreme drought event in the dry season 2015 - 2016 due to impacts of El Nino event (DWR, 2016).

Recent years, the global warming issue is considered as the major factor for increasing extreme events in terms of frequency and intensity (IPCC, 2007, 2013). In Vietnam, many climate changes scenarios have been published by Ministry of Natural resources and Environment (MONRE) since 2009 (MONRE, 2009, 2012, 2016). These scenarios showed the increasing

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trend of temperature in the future according to GHG scenarios.

In 2016, MONRE published the "Climate change and sea level rise scenarios for Vietnam" based on the calculations of IMHEN (IMHEN, 2016). Where, the information of temperature and rainfall as well as some of its extreme events that can be found. However, the very important information is drought condition is not detected. Thus, the drought condition detected by these bias-corrected rainfall projections is very important information for implementing responding to climate change. Especially, the information related to the drought projection is significantly required for assessment of climate change on many important sectors. From these mentioned above, we try to detect the drought projection for the South-Central region that is calculated by the bias-correction rainfall collected from IMHEN (2016).

2. Data and method

2.1. Data collected

In this study, we collected daily rainfall for 11 stations (Table 1) from sources as listed as:

- Daily rainfall observed: The 1975-2017 daily rainfall is collected from VMHA.

- Daily rainfall projected according to RCP4.5 and RCP8.5 scenarios: In this study, the bias-correction daily rainfall for 1980 - 2005, 2046 - 2065 and 2080 - 2099 is collected from IMHEN (IMHEN, 2016). The Table 2 presents the number of the projections that are used in this study.

Table 1. List of stations used in the study

No.	Name of station	Longitude	Latitude
1	Da Nang	108.18	16.03
2	Tam Ky	108.5	15.55
3	Tra My	108.21	15.35
4	Ba To	108.71	14.76
5	Quang Ngai	108.78	15.13
6	Hoai Nhon	109.01	14.53
7	Quy Nhon	109.21	13.76
8	Son Hoa	108.98	13.05
9	Tuy Hoa	109.28	13.08
10	Nha Trang	109.2	12.25
11	Cam Ranh	109.16	11.95

Table 2. Simulations and projections used in the study (IMHEN, 2016)

No.	Regional climate models (RCMs)	Global climate models (GCMs)	Resolution of RCMs
1	CCAM	ACCESS1-0	10km
2		CCSM4	
3		CNRM-CM5	
4		GFDL-CM3	
5		MPI-ESM-LR	
6		NorESM1-M	
7	RegCM	ACCESS1-0	20km
8		NorESM1-M	
9	PRECIS	HadGEM2-ES	25km
10		GFDL-CM3	
11		CNRM-CM5	
12	CLWRF	NorESM1-M	30km
13	MRI-20km_A	NCAR-SST	20km
14	MRI-20km_B	HadGEM2- SST	
15	MRI-20km_C	GFDL - SST	
16	MRI-20km_D	Tổ hợp SST	

2.2 Methods of study

Definition of the drought condition:

The Standardized Precipitation Index (SPI) is used to define the drought condition (WMO, 2012). The SPI was designed to quantify the precipitation deficit for multiple timescales. These timescales reflect the impact of drought on the availability of the different water resources. Soil moisture conditions respond to precipitation anomalies on a relatively short scale. Groundwater, streamflow and reservoir storage reflect the longer-term precipitation anomalies. For these reasons, McKee et al. (1993) originally calculated the SPI for 3-, 6-,12-, 24- and 48-month timescales.

The SPI calculation for any location is based on the long-term precipitation record for a desired period. This long-term record is fitted to a probability distribution, which is then transformed into a normal distribution so that the mean SPI for the location and desired period is zero (Edwards and McKee, 1997). Positive SPI values indicate greater than median precipitation and negative values indicate less than median precipitation. Because the SPI is normalized, wetter and drier climates can be represented in the same way; thus, wet periods can also be monitored using the SPI.

In recent years, the SPI for 3-, 6-,12-, 24- and 48-month timescales are used to define the drought condition of many types of drought as Meteorological, Agriculture and Hydrological drought conditions, respectively (WMO, 2012; Liu et al., 2013; James et al., 2015; Marzena Osuch et al., 2016; Dongwoo Jang, 2018).

SPI is defined by the below equation (WMO, 2012):

$$SPI = \frac{R - \bar{R}}{\sigma} \quad (1)$$

where σ is the standard deviation of rainfall; R and $\bar{R}$ are the rainfall and climatology rainfall, respectively.

In general, the drought condition occurs when the SPI<0 (Thang et al., 2007; Tri et al., 2015; WMO, 2012). In this study, the extreme drought event is defined by the minimum value of the SPI (called as SPI_min). Thus, the trend of SPI_min means that the trend of the most extreme drought condition is defined.

As mentioned above, the drought and extreme drought conditions are considered for many timescales of 1-, 3-, 6- and 12-month (SPI_1, SPI_3, SPI_6 and SPI_12). As mentioned by WMO (2012) and many studies (Thang et al, 2007; Tri et al., 2015), we can define many types of drought based on the timescales of SPI as:

- SPI_1: Meteorological drought
- SPI_3 and SPI_6: Agriculture drought;
- SPI_12: Hydrological drought.

Definition of the drought trend:

For identifying the drought trend in the South-Central, we use the simple linear regression equation as used in many studies (IPCC, 2007, 2013; MONRE, 2009, 2012, 2016; Thang et al., 2015).

Given a data set X: $x_1, x_2, x_3, \ldots, x_n$ of n statistical units.

Consider the simple linear equation:

$$x_t = b_0 + b_{1t} \quad (2)$$

where

$$b_1 = \frac{\sum_{t=1}^{n}(x_t - \bar{x})(t - \bar{t})}{\sum_{t=1}^{n}(t - \bar{t})^2}$$

$$b_0 = \bar{x} - b_1\bar{t}$$

We can find:

- b_1: the slope of the fitted line (linear changing rate)
- b^o: mean value mass of the data points

From that, we can find the increase/decrease rate of the duration study as: $D=b_1 n$ (3)

where n is sample sizes.

We can define the correlation coefficient (r_{xt}):

Definition of the change rate of projection:

The change of projection is defined by comparing the future SPI (or SPI_min) with baseline SPI (or SPI_min). These two future periods are the period of 2046 - 2065 and 2080 - 2099. The baseline period is 1986 - 2005. The change of

SPI (or SPI_min) is defined by the below equation as:

$$\Delta SPI_{future} = \frac{\left(SPI^*_{future} - \overline{SPI^*_{1986\text{-}2005}}\right)}{SPI^*_{1986\text{-}2005}} * 100$$

Where ΔSPIfuture is the future change rate (%) of SPI (or SPI_min); SPI^*_{future} and $SPI^*_{1986\text{-}2005}$ are the future SPI (or SPI_min) and past SPI (or SPI_min), respectively.

In this study, the SPI index is calculated by mean ensemble of the bias-correction rainfall projections for each scenario and each period.

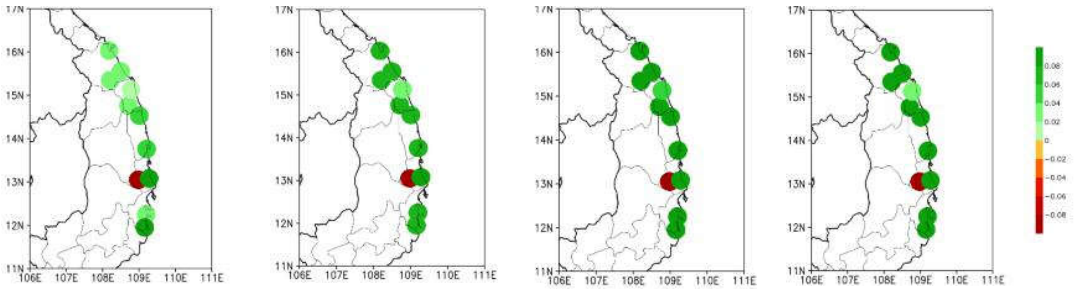
3. Results of study

3.1 Assessment of the past drought condition in the South - Central region

Results of the 1975 - 2017 trend of the SPI at timescales are presented in the Fig.1. In general, the increasing trend of SPI is found at most of stations. The increasing rate of SPI is found from 0.02 to 0.06/decade. In which, the increasing rate of longer timescales is higher than shorter timescales. This trend means that the decrease trend of mean drought condition at all timescales. This decreasing trend of the mean drought condition is ordered by the increase trend of the rainfall projection (see more trend of rainfall in MONRE, 2016).

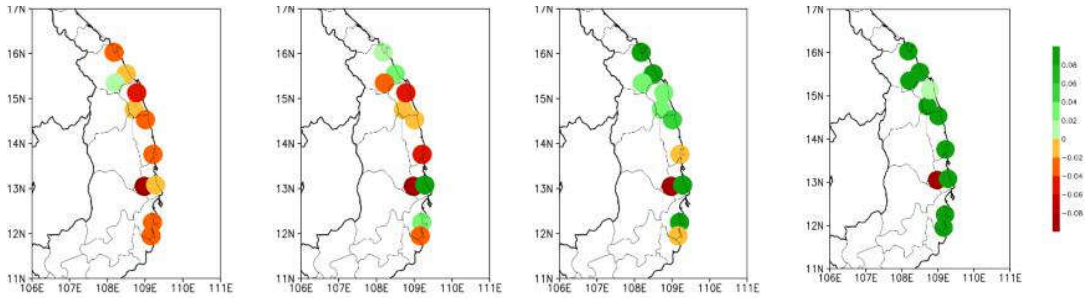
Remarkably, the important result is that the increase trend of the extreme drought condition is found (Fig. 2). As Fig. 2, we can find the significant decrease trend of SPI index at 1- and 3-month timescales. The decrease rate of SPI_min index at these two timescales is mostly from 0.02 to 0.06/decade at most stations. For 6-month timescale, the decrease trend of the SPI_min is only found at stations in the southern part of the South-Central. However, the increase trend is found at all stations (Fig. 2).

From these above analyses, the mean drought condition at all timescales is found as decreasing in intensity according to the increase of rainfall. However, the most extreme of drought at timescales from 1- to 3-month is found that increasing in intensity.



(a) (b) (c) (d)

Fig. 1. The change rate of the SPI index (unit/decade): (a) SPI_1, (b) SPI_3, (c) SPI_6 và (d) SPI_12



(a) (b) (c) (d)

Fig. 2. SPI_Min: (a) SPI_1, (b) SPI_3, (c) SPI_6 và (d) SPI_12

3.2 The projections of drought condition according to scenarios

3.2.1 Drought condition projections for 2016 - 2035

The Fig.3 shows the results of the changes in SPI (%) of 2016 - 2035 compared with baseline period at 1-, 3-, 6- and 12-month timescales. We clearly find increasing trends of SPI at all timescales. These results show that the mean drought condition in the South-Central region is expected to decrease compared with the baseline period. In general, the SPI of the 2016 - 2035 projected to increase by from 0 to 0.8% compared with the baseline period. The increasing rate of the shorter timescales (1- and 3-month) is smaller than longer timescale (6- and 12-month).

Comparing the Fig. 4 with the Fig. 3, according to both RCP4.5 and RCP8.5 scenarios, the significant difference between trend of SPI and SPI_min can be found. Meanwhile, SPI is defined by increasing trend of projections for all timescales at all stations as shown in the Fig.3. In contrast, SPI_min at 1- to 6-month timescales is defined by an obvious decreasing trend of projections at stations in the central and southern areas of the South - Central region as shown in the Fig.4. Comparing with the baseline period, the decreasing rate of the SPI_min from 2016 to 2035 is identified from 0 to 0.2%. Where, the higher decrease rate of SPI_min is found by projection according to the RCP8.5 (Fig. 4).

These results indicate that the mean drought condition in the South-Central during 2016 - 2035 is expected to decrease compared with the baseline period. However, the severity of drought condition is expected to increase at the central and southern stations, especially on the shorter timescales. The increasing trends of extreme drought at shorter timescales are found by both RCP4.5 and RCP8.5 projection scenarios. Although, the very long timescale (12-month), the increasing trend of extreme drought is not found by these projections.

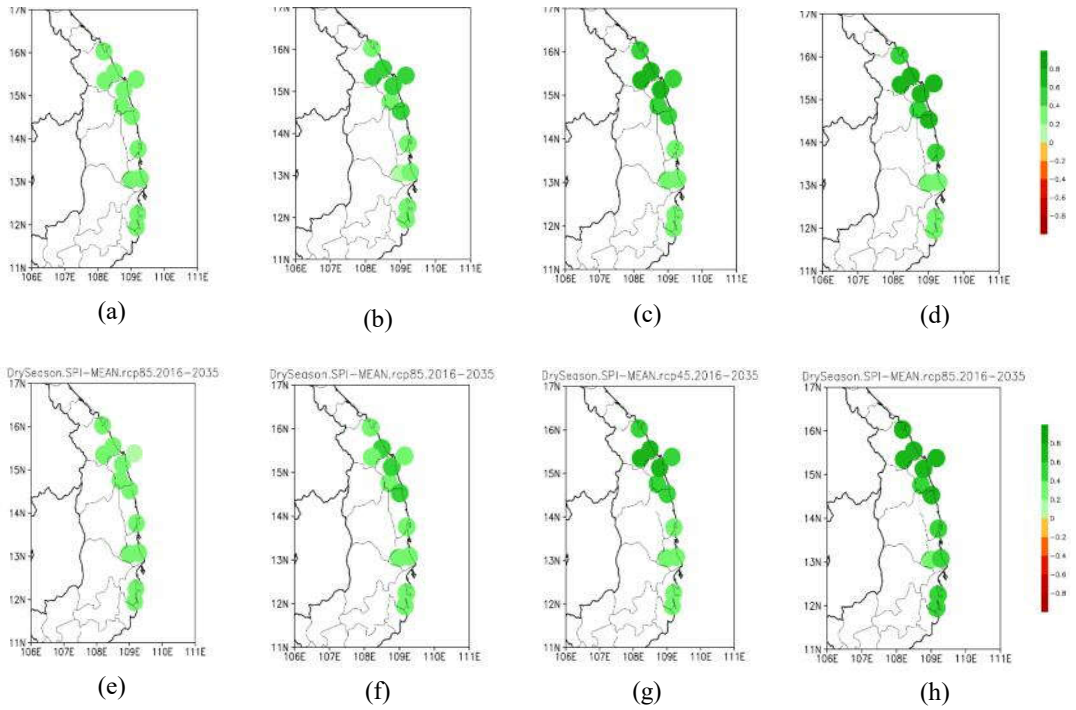


Fig. 3. Changes in SPI index (%) at timescales calculated from bias-correction rainfall for 2016-2035 compared with baseline period according to RCP4.5 (above maps) and RCP8.5 (below maps) scenarios: SPI_1 (a, e), SPI_3 (b, f), SPI_6 (c, g) and SPI_12 (d, h)

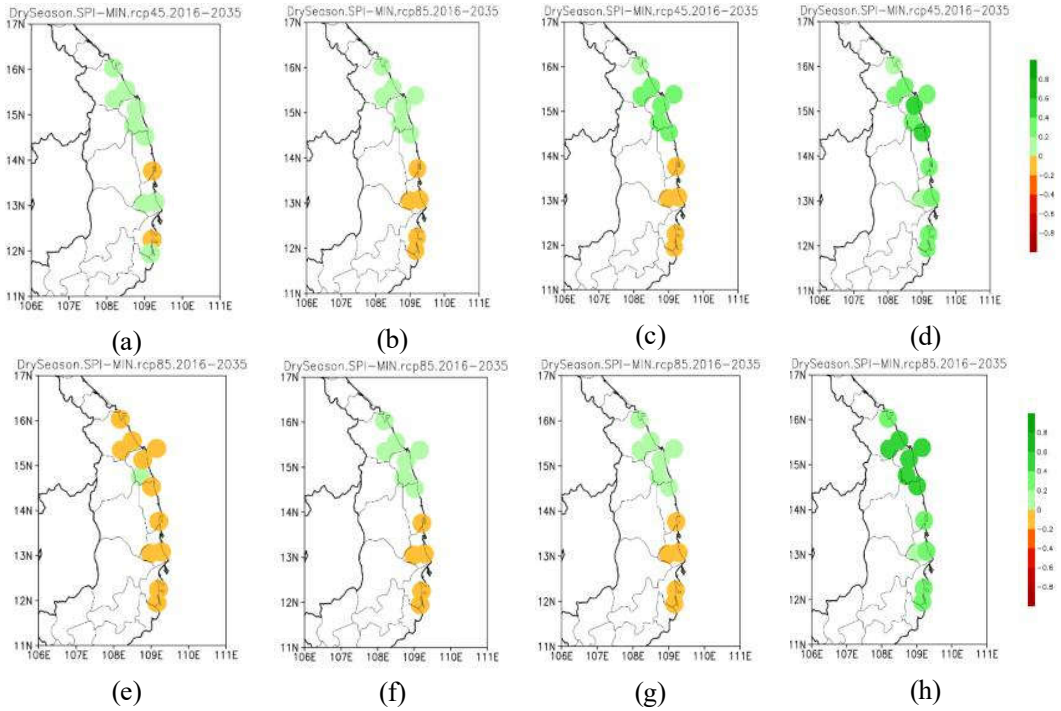


Fig. 4. SPI_Min: SPI_1 (a, e), SPI_3 (b, f), SPI_6 (c, g) and SPI_12 (d, h)

3.2.2 Drought condition projections for the period of 2046 - 2065

For the mid -21st century (2036 - 2065) (Fig. 5 and Fig. 6), the trend projections of SPI and SPI_min are similar to that of the 2016 - 2035 period examined by both RCP4.5 and RCP8.5 scenarios.

In general, the mean drought condition of the 2036 - 2065 period in the South - Central region is found less than the baseline period. The increasing rate of SPI is found from 0.2 to 0.8% compared with the baseline period. The most increasing rate is found by the SPI at the longer timescales (Fig. 5).

The interesting results that the severity extreme of the drought condition defined by SPI_min is shown in Figure 6. As expected for the beginning period of the 21st century, the trend of SPI_min is found by decreasing trends at most of stations in the central and southern part of the South-Central region, especially for drought condition at the shorter timescales. The decreasing rate of the SPI_mean ranged from 0 to 0.2% compared with the baseline period (Fig.6). Comparing the Fig.6 with Fig.4, we can find the significant differences that the extreme drought of 2036 - 2065 period according to RPC8.5 scenario is found by increasing trends for all timescales.

For the projections of the period 2036 - 2065, this means that the extreme drought according to RCP4.5 scenario at shorter timescales is expected to increase. However, the RCP8.5 scenario shows the increasing trend of extreme drought at all timescales. In addition, the number of the station that having the increasing trend according to RCP8.5 scenario is higher than RCP4.5.

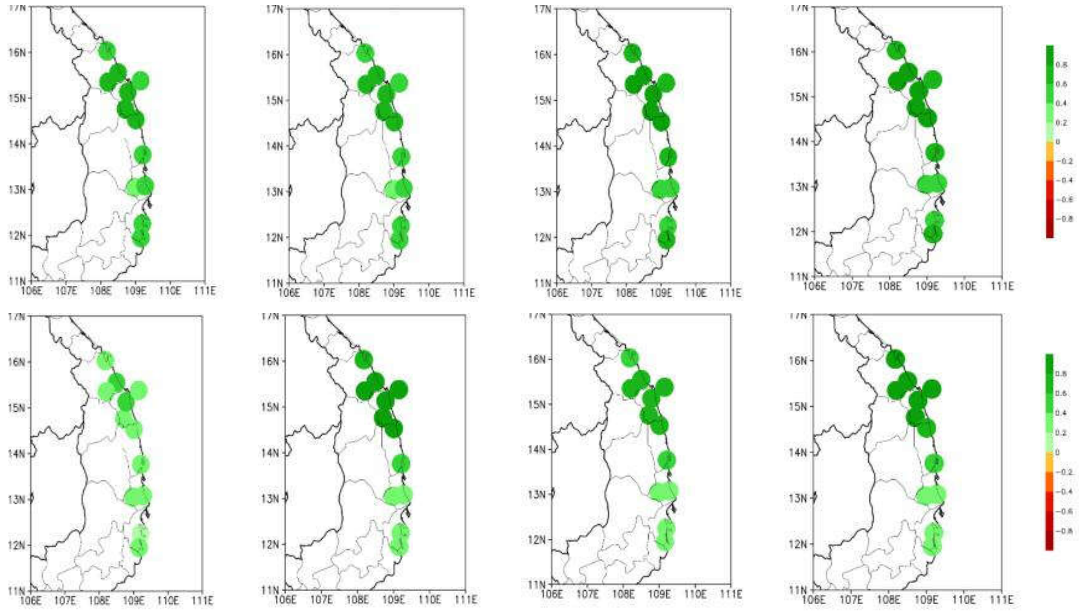


Fig.5. Same as Fig.3. but for 2046-2065: SPI_1 (a, e), SPI_3 (b, f), SPI_6 (c, g) and SPI_12 (d, h)

g g _ ( ) _ ( ) _ (g) and SPI_12 (d, h)

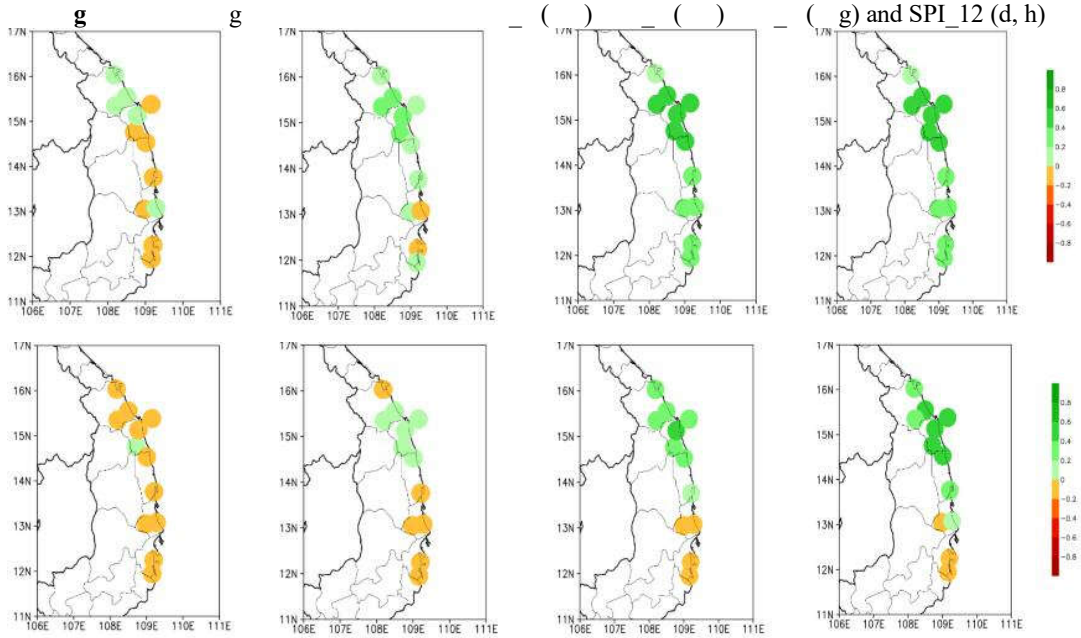


Fig.6. Same as Fig.5. but for SPI_Min: SPI_1 (a, e), SPI_3 (b, f), SPI_6 (c, g) and SPI_12 (d, h)

3.2.3 Drought condition projections for 2080-2099

For the end - 21st century (2080 - 2099), the trends of SPI and SPI_min are projected by the same trend with the beginning and mid - 21st century.

Fig. 7 shows that the SPI at all timescales of 2080 - 2099 is higher than that of the baseline period. The increasing rate of the period 2080 - 2099 compared with baseline ranged from 0 to 0.8%. Whereas, the increase of SPI index at longer timescales is higher than shorter timescales. This means that the changes in mean drought condition at shorter timescales are not clearly found, especially at southern stations of the region. The noticeable increasing trend of drought condition is found at longer timescales.

As like the 2016-2035 and 2036-2065 peri-

ods, the SPI_min of 2080 - 2099 varied from smaller values than that of the baseline period. However, these smaller values are mostly found at the SPI_min at 1- and 3-month timescales (Fig. 8). This means that the extreme drought of 2080 - 2099 at shorter timescales is expected to be more serious than that of the baseline period.

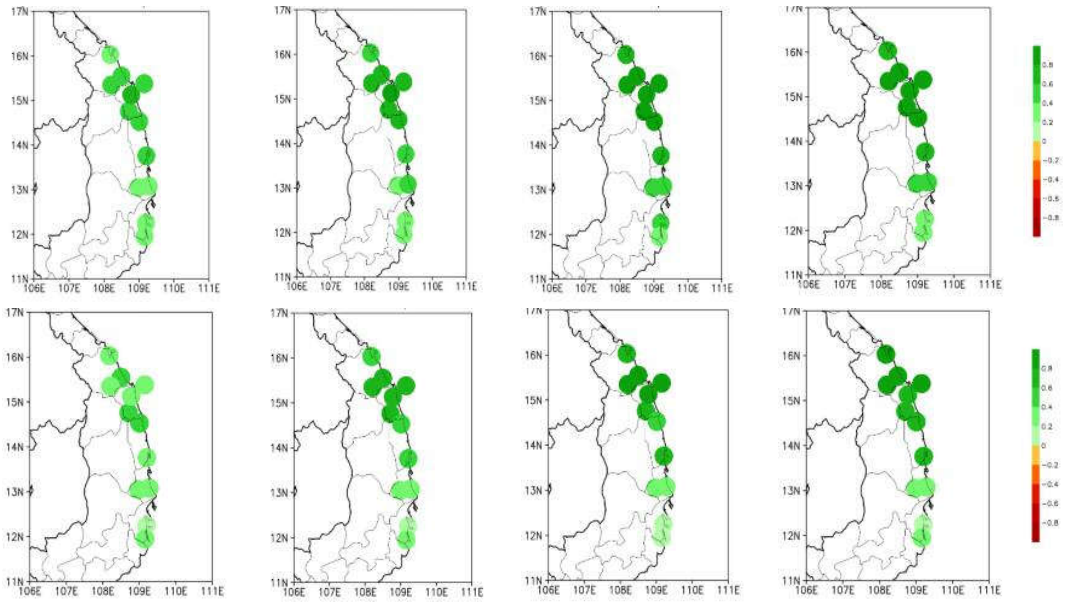


Fig. 7. Same as Fig.3. but for 2080-2099: SPI_1 (a, e), SPI_3 (b, f), SPI_6 (c, g) and SPI_12 (d, h)

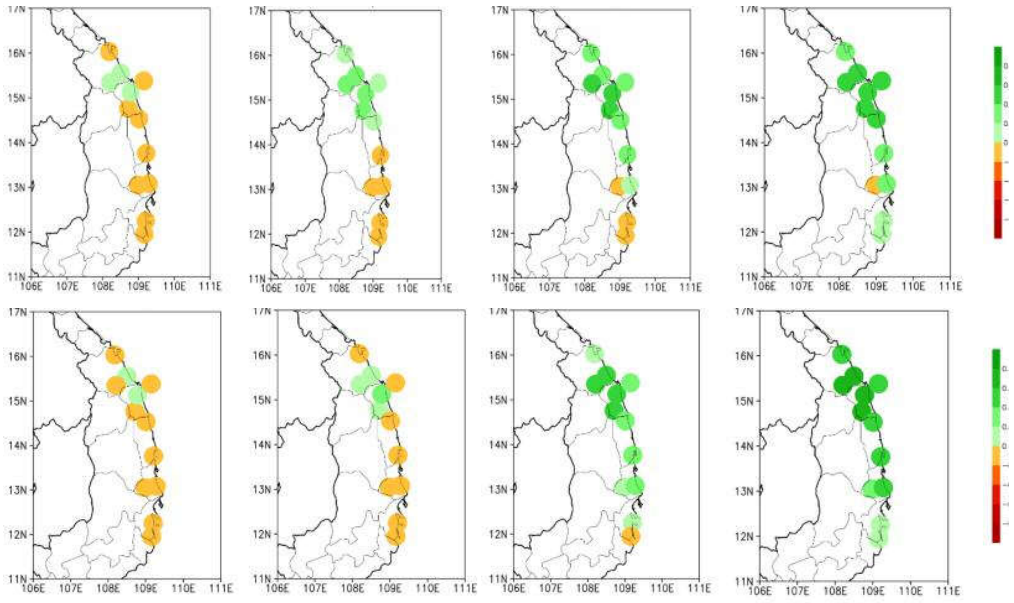


Fig.8. SPI_Min: SPI_1 (a, e), SPI_3 (b, f), SPI_6 (c, g) and SPI_12 (d, h)

4. Conclusion and discussion

4.1. Conclusion

From these calculations and analysis above which based on the past observed data and future bias-correction rainfall, some conclusions can be drawn:

(1) The SPI calculations for multiple timescales show the average wetter condition trend during 1961- 2017. However, the changes

in drought condition at the central and southern stations in the South-Central region is not significant. Especially, the most extreme of drought condition is detected by increase in severity level due to the decrease trend of the SPI_min index.

(2) The future trends (2016 - 2035, 2036 - 2065 and 2080 - 2099 periods) of SPI and SPI_min indices according to both RCP4.5 and RCP8.5 scenarios are generally found the same pattern with that of the past trend. Whereas, the future mean drought condition at four timescales is expected to decrease. The slight increase rate of future SPI index is found by the central and southern stations of the South-Central region and by the shorter timescales. Although the decreasing trend of mean drought examined, the increasing trend of the most extreme drought condition is found according to both RCP4.5 and RCP8.5 scenarios. This increasing trend of the most extreme drought condition is significantly found by the shorter timescales and by the central and southern stations in the South-Central region.

4.2. Discussion

In this study, we try to find the changes in drought condition of the future periods compared with the baseline period based on the bias-cor-rection rainfall of IMHEN. This bias-correction rainfall was used in the *"Climate change and sea level rise scenarios"* published by MONRE. Thus, our results are presented in this study that can provide useful information for implement-ing responding to climate change in the South-Central region.

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