ASSESSMENT OF DROUGHT CONDITIONS IN THE RED RIVER DELTA

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Abstract: *The standardized precipitation index (SPI) is used to analyse drought conditions in the past 54 years (1961-2014) and to assess possible drought conditions in the 21st century under the RCP4.5 and RCP8.5 scenarios for the Red River Delta. The results show that with different timescales, the drought conditions of the Red River Delta tended to increase during the period of 1961-2014. Compared to the baseline period (1986-2005), the number of drought spells are likely to decrease in the future under both scenarios. The projected drought changes of the 1-, 3-month timescales are smaller than those of the 6-, 12-month timescales. Remarkably, the drought intensity of 1-, 3-month timescales is likely to be more extreme by the end-21st century under both RCP4.5 and RCP8.5.*

Keywords: *SPI, drought, Red River Delta.*

1. Introduction

Drought is one of the most common natural disasters in Viet Nam that seriously affects environment, economy, society and human health. According to the World Meteorological Organization, drought can be classified into four groups: meteorological, hydrological, agricultural and socio-economic drought [15]. Unlike other types of natural disasters, the effects of drought often accumulate slowly over a considerable period of time and may last for years after the termination of the drought event. As a result, the meteorological drought often occurs firstly, followed by agricultural and hydrological droughts. Recently, due to the effects of climate change, droughts have increased in intensity and frequency, significantly affecting agriculture, forestry, industry, water resources, hydroelectric power generation, natural environment and human life, etc. in the country's regions. In particular, the Red River delta and the Mekong River Delta are two regions affected most seriously. Therefore, drought studies are of interest for researchers, policy makers and localities.

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The Red River Delta has the highest population density, is the political, economic and cultural center, and is one of the two biggest food resources in Viet Nam. Since 1993, droughts have been continuously occurring on a large scale in this region owing to the depletion of water resource due to increasing demand for water for daily life and agricultural production [6]. Therefore, drought studies in this region to predict future drought are essential to minimize risks and damages coursed by drought. In the Red River Delta, the frequency of drought is quite high in the winter months, early spring (November, January, March) and very low in the summer and autumn months. The main cause of drought in this region is the deficit of precipitation and flows, especially extreme droughts become very severe during El Niño events.

From what have mentioned above, the study focuses on analysing and evaluating past trends and projecting future changes in drought conditions for the Red River Delta based on the latest results of the Ministry of Natural Resources and Environment and the Intergovernmental Panel on Climate Change (IPCC). This study can provide the latest and most important information on drought changes in the future.

There are a number of drought indices that have been applied internationally as well as in Viet Nam to study drought; however, this study uses the standardized precipitation index (SPI). The SPI is a simple and effective index to reflect drought condition. The SPI is based on just one variable (rainfall) and can be calculated for 3-, 6-, 12-, 24-, 48-month timescales; therefore, the researchers, policy makers greatly appreciate for its diversity.

2. Data and methodology

2.1. Data

(1) Observed data

The daily precipitation data updated to 2014 from 12 observation stations in the Red River Delta have been used in this analysis (Table 1).

(2) Model data

The daily precipitation data of PRECIS model during reference period (1986-2005) and future projections (2016-2035, 2046-2065, 2080-2099) under RCP4.5 and RCP8.5 scenarios were used for calculation. For the study purposes, quantile mapping correction method was chosen to correct the bias of PRECIS model simulations in comparison with the observational data.

Table 1. Observed stations of the Red River Delta during 1961-2014

Order	Stations	Longitude	Latitude	Data period
1	BA VI	105.40	21.08	1969 - 2014
2	HA DONG	105.77	20.97	1973 - 2014
3	SON TAY	105.50	21.13	1961 - 2014
4	HA NOI	105.85	21.02	1961 - 2014
5	CHI LINH	106.38	21.10	1961 - 2014
6	HAI DUONG	106.30	20.95	1961 - 2014
7	HUNG YEN	106.05	20.67	1961 - 2014
8	NAM DINH	106.17	20.43	1961 - 2014
9	VAN LY	106.30	20.12	1961 - 2014
10	THAI BINH	106.35	20.45	1961 - 2014
11	NINH BINH	105.98	20.27	1961 - 2014
12	NHO QUAN	105.73	20.32	1961 - 2014

2.2. Methodology

The standardized precipitation index (SPI) is used for assessing drought conditions of the Red River Delta. The SPI is a widely used drought index and was developed by McKee et al. (1993) [5]. According to McKee et al. (1993), the SPI was defined on each of the time scales as the difference of precipitation (R) from mean value ($\overline{R}$) for a specified time period and then divided by the standard deviation (σ) where the mean value is determined, i.e.

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

The SPI is a dimensionless index. The SPI was designed to quantify the precipitation deficit for different timescales which depends on the study purpose, for example a 1- or 2-month SPI for meteorological drought, from 1-month to 6-month SPI for agricultural drought, and 6-month up to 24-month SPI or more for hydrological drought analyses and applications [12]. Positive SPI values indicate that precipitation is greater than median precipitation, and negative values indicate that precipitation is less than median precipitation, i.e. it indicates dry and wet conditions respectively. The larger the negative values of SPI are, the more severe the drought is. Drought state ends when the SPI

values are positive. Extreme drought conditions of the Red River Delta are defined as the minimum SPI values (MIN_SPI) in the dry season.

In this study, the SPI and MIN_SPI are calculated for timescales including 1-month (SPI1, MIN_SPI1), 3-month (SPI3, MIN_SPI3), 6-month (SPI6, MIN_SPI6) and 12-month (SPI12, MIN_SPI12).

Projected changes under RCP4.5 and RCP8.5 scenarios:

Projected changes in the SPI (%) under RCP4.5 and RCP8.5 scenarios in the future (2016-2035, 2046-2065, 2080-2099) compared to the baseline period (1986-2005) is computed as follow:

$$\Delta SPI = \frac{(SPI_{future} - SPI_{1986-2005})}{SPI_{1986-2005}} * 100 \quad (2)$$

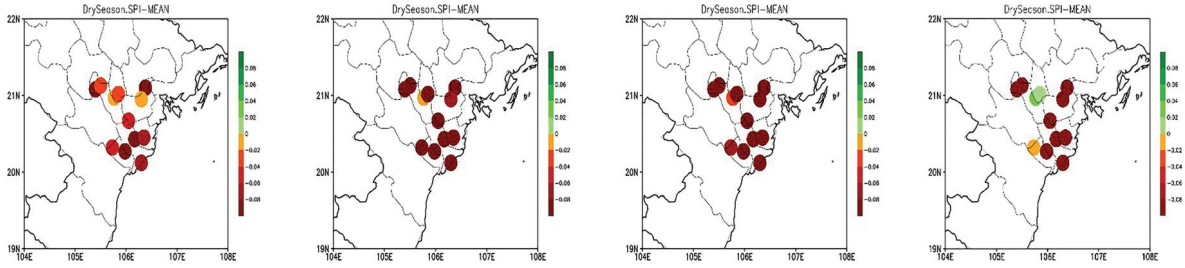
Where: ΔSPI_{future} is the difference between SPI in the future and SPI in the baseline period (%). SPI^*_{future} and $SPI^*_{1986\text{-}2005}$ are the mean SPI values in the future periods and the baseline period respectively.

3. Results and discussion

3.1. Trends of drought in the past

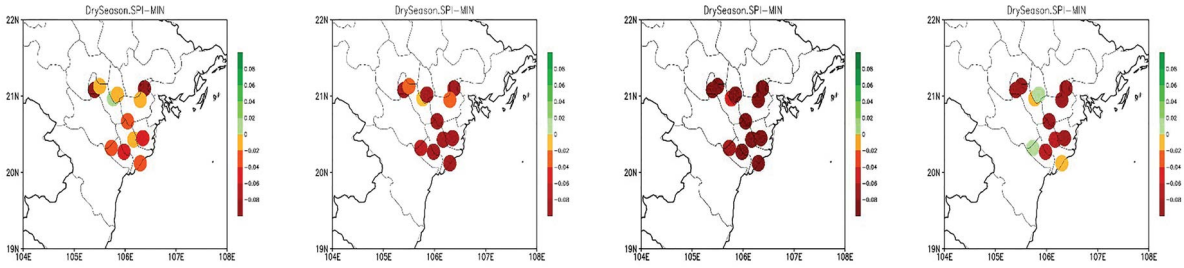
Figure 1 shows observed trends in the dry season SPI index in the Red River Delta at the 1-, 3-, 6-, 12-month timescales between 1961 and 2014. In general, the SPI tended to decrease by 0.02-0.08 unit per decade at the 1-month timescale, above 0.08 unit per decade at the 3-, 6-, 12-month timescales. Therefore, the drought condition in the Red River Delta tended to increase during the period of 1961-2014 with the most obvious trends at the 3-month and 6-month timescales.

The extreme drought conditions also had increasing trends in most areas at the 1-, 12-month timescales, and over the entire Red River Delta at the 3-, 6-month timescales (Figure 2). To specific, the MIN_SPI shows upward trends during 1961-2014 with the rate of the MIN_SPI increase at the 3-, 6-month timescales being faster than that at the 1-, 12-month timescales.



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

Figure 1. Observed trends of SPI index for 1-, 3-, 6-, 12-month timescales: (a) 1-month, (b) 3-month, (c) 6-month, (d) 12-month



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

Figure 2. Observed trends of MIN_SPI index for different timescales: (a) 1- month, (b) 3-month, (c) 6-month, (d) 12-month

3.2. Future changes in drought condition

3.2.1. The beginning of the 21st century (2016-2035)

Under RCP4.5 and RCP8.5, at the beginning of the 21st century, the drought conditions of the Red River Delta in dry season are likely to decrease relative to the baseline period (1986-2005). Figure 3 shows that compared with the baseline period, dry season SPI is projected to increase by 0 to above 0.8% at the beginning of the 21st century with the projected changes of SPI1 and SPI3 being smaller than those of SPI6 and SPI12.

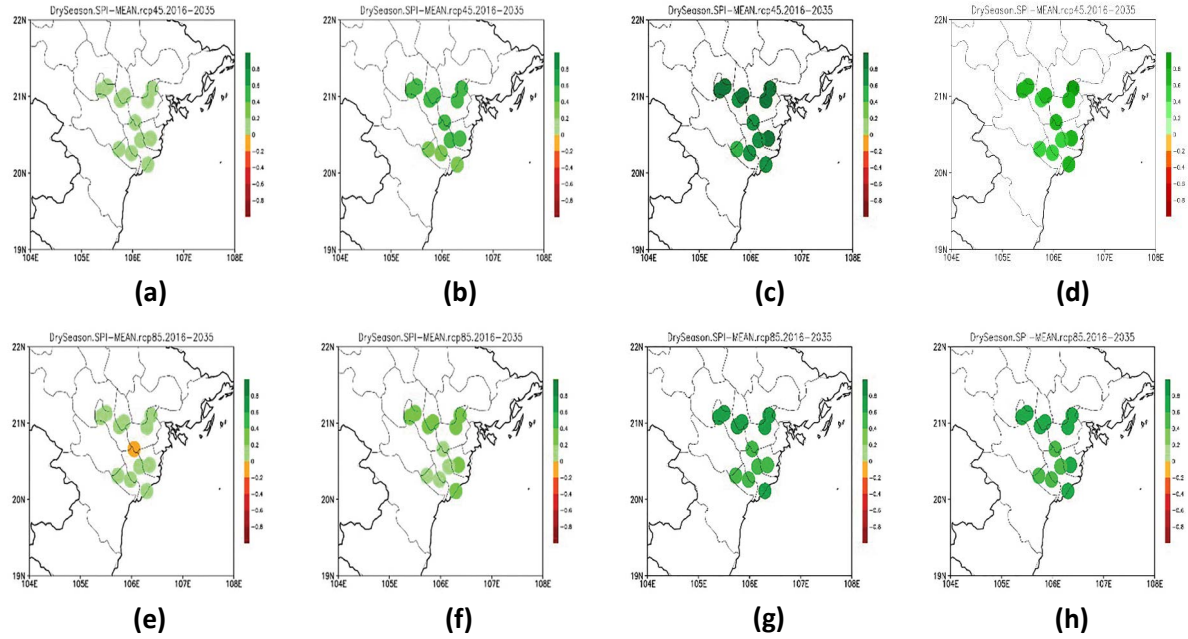


Figure 3. Percentage changes (%) of dry season SPI for 2016-2035 average relative to 1986-2005 average under RCP4.5 and RCP8.5 for timescales: 1-month (a, e), 3-month (b, f), 6-month (c, g), 12-month (d, h)

However, under both scenarios, at the beginning of the 21st century, compared to the baseline period, extreme drought condition is likely to increase in the Red River Delta at the 1-month timescale (i.e. the MIN_SPI1 is projected to decline) and decrease in this region at the 6-, 12-month timescales (i.e. MIN_SPI6 and MIN_SPI12 are projected to rise) (Figure 4). For the 3-month timescale, compared to the baseline period, extreme drought conditions are projected to be different between RCP4.5 and RCP8.5 scenarios. Extreme drought conditions of the 3-month timescale are likely to decline in most of the region under RCP4.5 scenario and rise over the entire region under RCP8.5 scenario.

3.2.2. The middle of the 21st century (2046-2065)

In the middle of the 21st century (2046-2065), projected changes in SPI under both scenarios are quite similar. The SPI is projected to slightly increase by 0-0.6% at the 1-, 3-month timescales and 0.6 to more than 0.8% at 6-, 12-month timescales (Figure 5). This indicates that by the middle of the 21st century, the drought conditions of the Red River Delta are likely to decline compared to the baseline period. In comparison with the baseline period, the extreme drought conditions of the Red River Delta by the middle of the 21st century are likely to decrease under both scenarios at the 6-, 12-month timescales, but projected changes are different between RCP4.5 and RCP8.5 scenarios at the shorter-time scales (Figure 6). For the 1-, 3-month timescales, extreme drought conditions are projected to decrease under RCP4.5 scenario (i.e. the

projected MIN_SPI is rise and increase in most of the region under RCP8.5 scenario (i.e. the projected MIN_SPI is decline).

3.2.3. The end of the 21st century (2080-2099)

Similar to the mid-21st century, projected changes in SPI under both scenarios by the end of the 21st century (2080-2099) are quite similar. The SPI is projected to slightly increase by 0-0.4% at the 1-month timescale, 0.2-0.6% at the 3-month timescale and 0.6% to more than 0.8% at 6-, 12-month timescales (Figure 7). In other words, by the end of the 21st century, compared to the baseline period, the drought conditions are likely to decrease in the Red River Delta where projected changes of the 1-, 3-month time scales are smaller than those of the 6-, 12-month time scales.

Under RCP4.5 and RCP8.5 scenarios, by the end of the 21st century, extreme drought conditions are likely to increase in the Red River Delta at the 1-month timescale and decrease in this region at the 6-, 12-month timescales. Figure 8 show that the MIN_SPI is projected to decrease by 0-0.2% at the 1-month timescale, increase by 0.2-0.6% at the 6-month timescale and 0.6% to above 0.8% at the 12-month timescale. For 3-month timescale, compared to the baseline period, extreme drought conditions are likely to decrease in the Red River Delta. The MIN_SPI3 is projected to decrease by 0-0.2% in much of the region under RCP4.5 scenario and over the entire region under RCP8.5 scenario by the end of the 21st century.

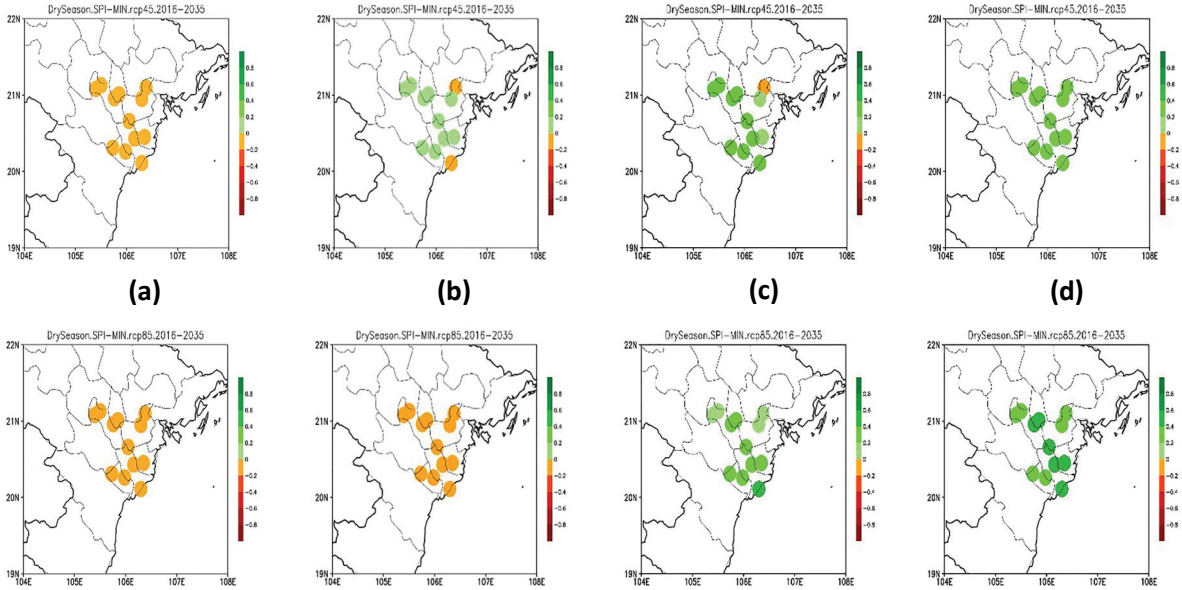


Figure 4. Projected changes in dry season MIN_SPI (%) for 2016-2035 average compared to 1986-2005 average under RCP4.5 and RCP8.5 for timescales: 1-month (a, e), 3-month (b, f), 6-month (c, g), 12-month (d, h)

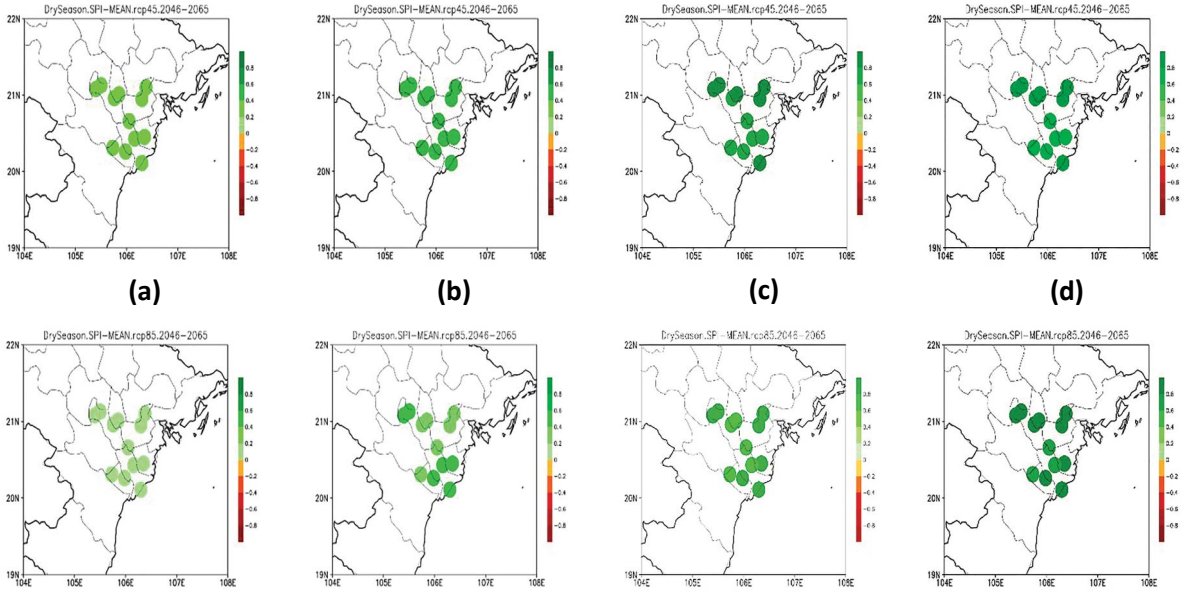


Figure 5. Percentage changes (%) of dry season SPI for 2046-2065 average relative to 1986-2005 average under RCP4.5 and RCP8.5 scenarios for timescales: 1-month (a, e), 3-month (b, f), 6-month (c, g), 12-month (d, h)

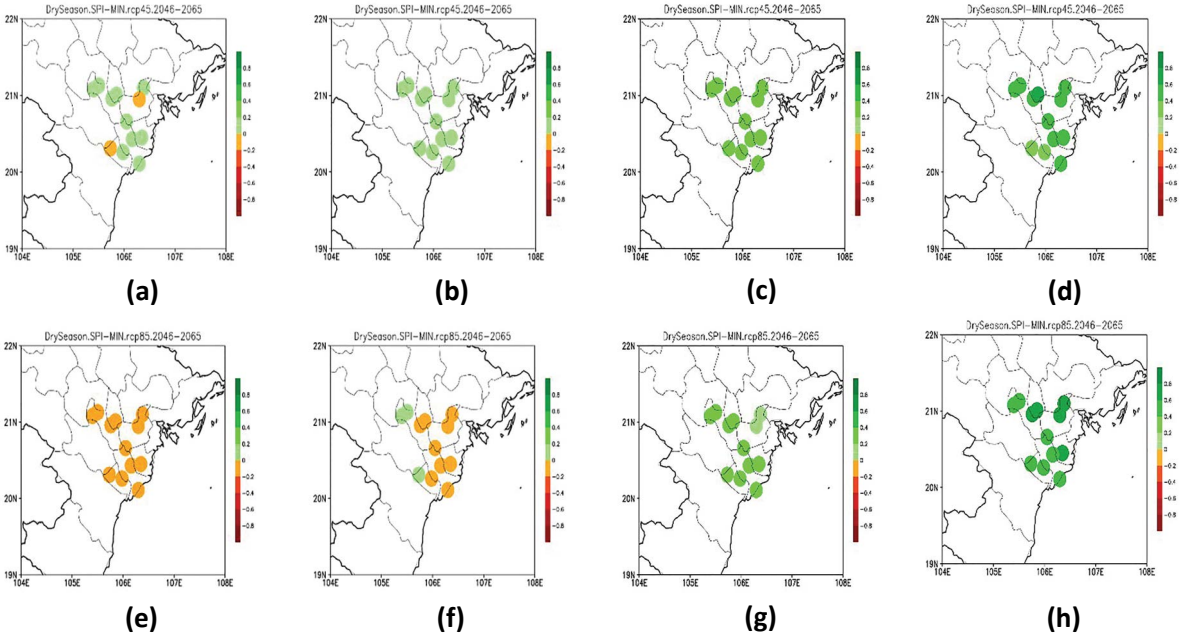


Figure 6. Dry season MIN_SPI changes (%) for 2046-2065 average relative to 1986-2005 average under RCP4.5 and RCP8.5 scenarios for scales: 1-month (a, e), 3-month (b, f), 6-month (c, g), 12-month (d, h)

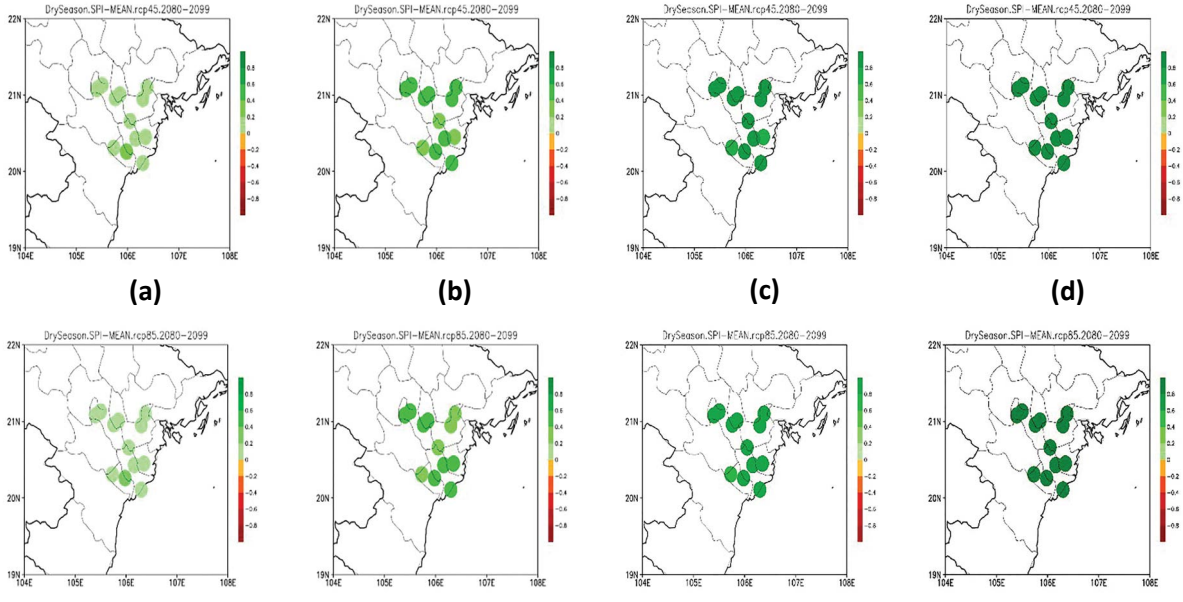


Figure 7. Projected changes in dry season SPI (%) for 2080-2099 average compared to 1986-2005 average under RCP4.5 and RCP8.5 for timescales: 1-month (a, e), 3-month (b, f), 6-month (c, g), 12-month (d, h)

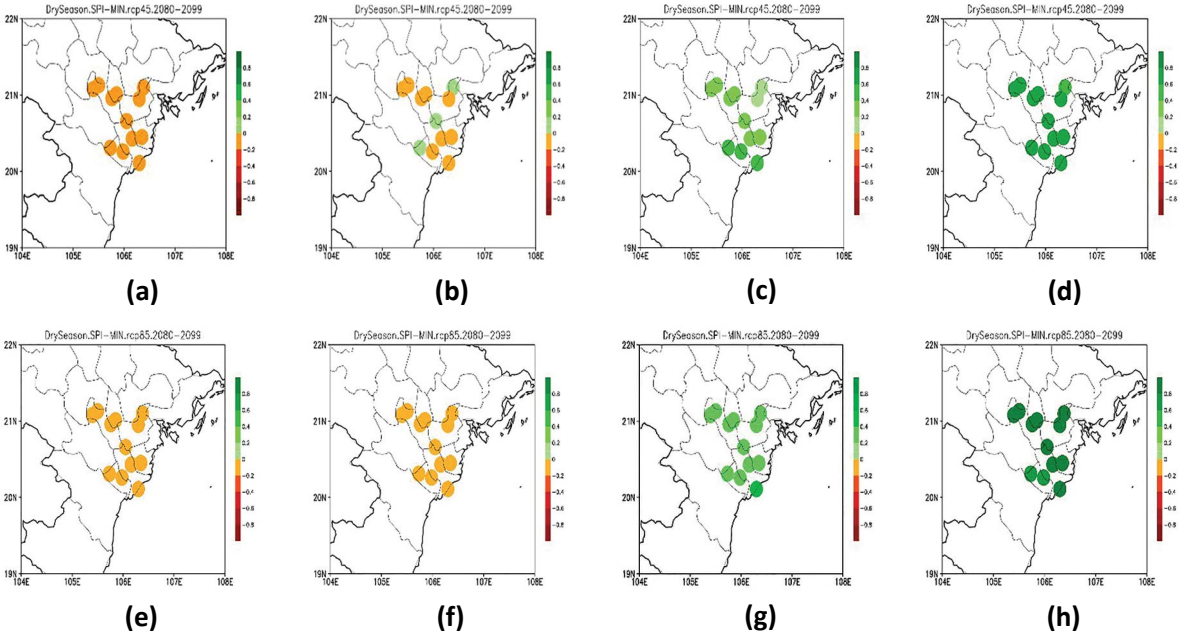


Figure 8. Dry season MIN_SPI changes (%) for 2080-2099 average relative to 1986-2005 average under RCP4.5 and RCP8.5 scenarios for timescales: 1-month (a, e), 3-month (b, f), 6-month (c, g), 12-month (d, h)

4. Conclusions

This study analyzed the drought conditions of the Red River Delta in the past 54 years (1961-2014) and assess possible drought conditions in the 21st century under the RCP4.5 and RCP8.5 scenarios. Rainfall data from 12 observed stations of the Red River Delta and SPI index are used for the study purposes. The results of analysis show that in dry season with different time scales, the drought and extreme drought conditions of the Red River Delta had upward trends during 1961-2014. The most obvious trends were found at the 3-, 6-month time scales. Under RCP4.5 and RCP8.5 scenarios, compared to the baseline period, the drought conditions of the Red River Delta are likely to decrease in the future with projected changes of the 1-, 3-month timescales being smaller than those of the 6-, 12-month timescales. It is worth noting that under both scenarios, extreme drought conditions are projected to increase at the 1-, 3-month timescales and decrease at the 6-, 12-month timescales by the end of the 21st century in comparison with the baseline period.

References

1. IPCC (2007), *Climate Change 2007: The Scientific Basis, Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.
2. Ministry of Natural Resources and Environment (2009), *Climate change, sea level rise scenarios for Viet Nam*, Viet Nam Publish House of Natural Resources, Environment and Cartography, Ha Noi.
3. Ministry of Natural Resources and Environment (2012), *Climate change, sea level rise scenarios for Viet Nam*, Viet Nam Publish House of Natural Resources, Environment and Cartography, Ha Noi.
4. Ministry of Natural Resources and Environment (2016), *Climate change, sea level rise scenarios for Viet Nam*, Viet Nam Publish House of Natural Resources, Environment and Cartography, Ha Noi.
5. McKee, T.B., Doesken, N.J. and Kleist, J. (1993), "The relationship of drought frequency and duration to time scales", *Preprints Eighth Conference on Applied Climatology*, Anaheim, CA. Am. Meteor. Soc., Boston, 179-184.
6. Nguyen, D.N. (2002), Understanding drought and desertification, Science and Technics Publishing House, Ha Noi, Viet Nam.
7. Nguyen, D.N. and Nguyen, T.H. (1991), *Climate change and its impacts on Viet Nam in the past 100 years*, Nature and people, National Political - Truth Publishing House, Ha Noi, Viet Nam.
8. Nguyen, D.N. and Nguyen, T.H. (1999), *Climate change situations in Viet Nam in the next decades*, Viet Nam Institute of Meteorology, Hydrology.
9. Nguyen, V.T. et al. (2010), *Study the impacts of climate change on natural conditions, natural resources and propose strategic solutions for prevention, mitigation and adaptation to serve sustainable socio-economic development in Viet Nam*, Final Report called KC.08.13 state/06-10. Viet Nam Institute of Meteorology, Hydrology and Environment, Ha Noi, Viet Nam.
10. Nguyen, V.T. et al. (2015), *Changes in Climate Extremes and Impacts on the Natural Physical Environment*, Viet Nam Publishing House of Natural resources, Environment and Cartography, Ha Noi, Viet Nam.
11. Nguyen, V. T. et al. (2017), "Changes in climate extreme in Viet Nam", *Viet Nam Science and Technology* (VISTECH). 1(1), 79-87.
12. WMO (2012), *Standardized Precipitation Index*, User guide, WMO-No. 1090.
13. Truong, D.T., Nguyen, D.M., Mai, V.K., Ha, T.M. and Dao, T.T. (2014), "Drought projections in the South Central region using the PRECIS model", *Scientific and Technical Hydro - Meteorological Journal*, (644).
14. IMHEN (2010), *The impacts of climate change on water resources and adaptation solutions in the Red River Delta*, Project Final Report.
15. WMO (2005), *Drought assessment and forecasting*.