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## Article

# Meteorological characteristics of the Mekong Delta in the period of 2014–2020

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**Abstract.** Meteorological data from 9 weather stations located in different provinces of the Vietnamese Mekong Delta were analyzed and compared in this study. The data analysis showed that in 2014–2020 the average annual temperature in the Mekong Delta was 27.6 °C, the total annual rainfall – 1533.9 mm, the average annual humidity – 79% or more, the total annual evaporation – 942.3 mm, and the total annual sunshine duration – 2521 hours. The average annual temperature in 2014–2020 was higher than that during the 1984–2013 period. Meanwhile, the total annual rainfall and the total annual evaporation in 2014–2020 were lower than that during the 1984–2013 period. Trend analysis of meteorological parameters from 2014 to 2020 showed that the average temperature during the dry season and the absolute minimum temperature at all weather stations tended to increase over time. The rainy season had a higher average daily temperature, more rainfall, and higher humidity, but lower evaporation, and lower sunshine hours than the dry season. The obtained data on the meteorological characteristics of the Vietnamese Mekong Delta lay the foundation for evaluating the dynamics of climate change, providing background for further research and developing solutions for the rational use of climate resources to promote the socio-economic development of this region.

**Keywords:** climate, temperature, rainfall, humidity, evaporation, sunshine

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**Научная статья****Метеорологические характеристики  
в дельте Меконга за период 2014–2020 гг.**

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**Аннотация.** В ходе работы были изучены показатели 9 метеостанций, расположенных в различных провинциях дельты р. Меконг. Данные, полученные за период 2014–2020 гг., были сопоставлены с показателями 1984–2013 гг. Проведенный анализ показал, что в 2014–2020 гг. средняя температура в дельте Меконга составляла +27.6 °С; сумма осадков – 1533.9 мм; средняя влажность – 79% и более; годовая сумма испарения – 942.3 мм; число часов солнечного сияния – 2521. По сравнению с 1984–2013 гг. среднегодовая температура имела тенденцию к повышению, а годовое количество осадков и годовая сумма испарения – к снижению. Оценка тренда изменения метеопараметров с 2014 г. до 2020 г. показала, что средняя температура во время сухого сезона и абсолютный минимум температуры на всех метеостанциях имели тенденцию к увеличению. Сезон дождей характеризовался увеличением среднесуточных температур, количества осадков, влажности, уменьшением испарения и количества солнечных часов по сравнению с сухим сезоном. Полученные данные о метеорологических характеристиках дельты Меконга станут основой для оценки динамики изменения климата, предоставления исходных данных для других исследований и выработки решений по рациональному использованию климатических ресурсов в целях содействия социально-экономическому развитию этого региона.

**Ключевые слова:** климат, температура, осадки, влажность, испарение, количество солнечных часов

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## Introduction

The Vietnamese Mekong Delta is located in the south of Vietnam, covering an area of about 40000 km<sup>2</sup>, accounting for 12% of the country's total natural area and 5% of the Mekong River basin area (Tran, 2013). This area holds a significantly crucial socio-economic standing within the nation, possessing the greatest potential for the development of the agricultural sector. At the same time, the Intergovernmental Panel on Climate Change has identified the Vietnamese Mekong Delta as one of the three most vulnerable deltas to sea level rise in the world<sup>1</sup>. In recent years, the impacts of climate change have gradually altered some natural conditions of the downstream area of the Mekong River, especially hydro-meteorological factors. The construction of mega-dams, which alters hydrological regime and leads to drought, saltwater intrusion, landslides and floods (Bonnema et al., 2020, Hoang et al., 2016, Lu and Chua, 2021, Meur. et al., 2021), is gradually threatening the Vietnamese Mekong Delta region. Climate change leads to diminishing agricultural land, elevated production costs, and a decline in both productivity and output. Many wetland conservation areas such, as Tram Chim, U Minh Thuong, Lang Sen, Tra Su, etc., are threatened. As a consequence, sustainability becomes more fragile, biodiversity is reduced, animals and plants, including rare ones, face an increasing risk of extinction. Analysis of the current status and evolution of meteorological factors in recent years is greatly essential. It will be the basis for assessing the climate change situation and developing solutions to adapt and forecast the climate change.

In this article, we would like to present meteorological characteristics of the Vietnamese Mekong Delta in the period of 2014–2020 through analysis and evaluation of meteorological data obtained at monitoring stations.

## Material and methods

The Vietnamese Mekong Delta shares its borders with the Southeastern region of Vietnam and is adjacent to Cambodia in the North, the Gulf of Thailand in the southwest, and the East Sea in the southeast. The Mekong Delta consists of 13 provinces and cities, namely: Long An, Tien Giang, Dong Thap, Vinh Long, Tra Vinh, Hau Giang, Soc Trang, Ben Tre, An Giang, Kien Giang, Bac Lieu, Ca Mau and Can Tho city which are centrally run (Fig. 1). The section of the river below Phnom Penh, extending downstream for 300 km, is considered to be the beginning of the Delta. In Vietnam, the Mekong river system divides into two main branches: the Mekong River (Tien River) and the Bat Sac River (Hau River), which in turn form a vast delta of 9 major branches flowing into the East Sea. The Vietnamese Mekong Delta has a flat and low terrain sloping down in 2 directions: from North to South and from West to East (Tran, 2013).

In this study we analyzed data obtained in 2014–2020 at 9 weather stations of the base network of the National Hydrometeorological Center located in the provinces of Tien Giang, Dong Thap, Vinh Long, Tra Vinh, Hau Giang, Soc Trang, Ben Tre, An Giang, and Can Tho City, as well as information provided by the Southern Regional Hydrometeorological Station (<http://www.siwr.org.vn/>) (Fig. 1). Meteorological factors selected for analysis and evaluation included temperature, rainfall, air humidity, evaporation, and hours of sunshine. Modern data (2014–2020) were compared with those obtained during the period 1984–2013, which predates the construction of large dams in the upstream of the Mekong River. These dams brought about fundamental alterations to the river's hydrological patterns. (Lu and Chua, 2021)

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<sup>1</sup> The Prime Minister of Vietnam. Decision No. 2139/QĐ-TTg of December 5, 2011. Approving the national strategy for climate change. (In Vietnamese).

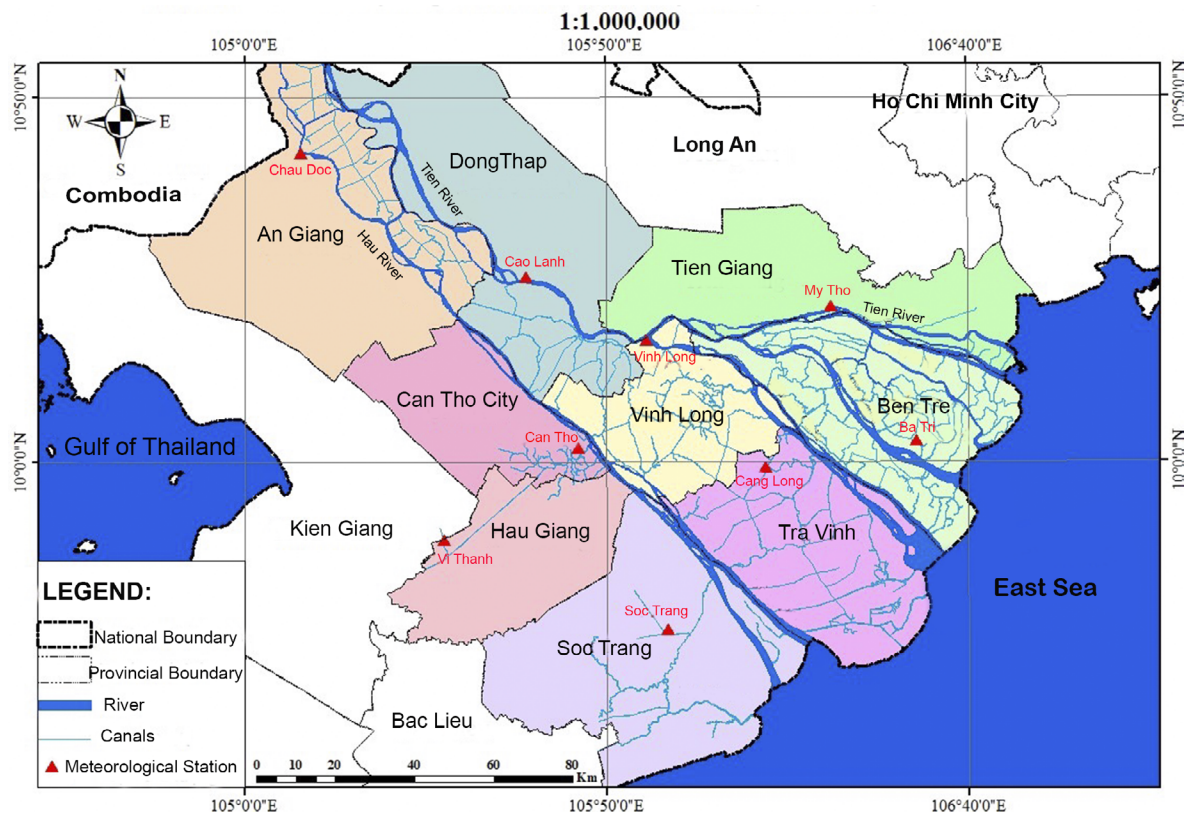


Fig. 1. Map of the study area and location of meteorological stations.

To determine the start and end dates of the rainy season, we used the method proposed by author Le Thi Xuan Lan et al. (Le, 2002). The start date of the rainy season is a day with the total rainfall  $\geq 5$  mm, total rainfall over the next 10 days  $> 50$  mm, and the humidity index  $K' > 1$  (ratio of rainfall to evaporation). In addition, there must be at least 5 rainy days within this 10-day interval, and after that there must be no gaps longer than 5 days between rainy days. The end date of the rainy season is a day with rainfall  $< 5$  mm, total rainfall over the next 10 days  $< 50$  mm, and the drought index  $K > 1$  (ratio of evaporation to rainfall). During this 10-day interval, there must be at least 5 rainless days, and after it there should be no periods with more than five rainy days in a row.

The nonparametric Mann–Kendall test (M–K test) was used to detect trends or changes over time; the Sen's slope method – to estimate the magnitude of the trend in a time series (slope of the trendline) (Kendall, 1975; Sen, 1968). The results were evaluated based on statistical analysis at a significance level of  $\alpha < 0.1$  (the probability of committing a Type-I error is 10%). Standard deviation (S) and coefficient of variation (Cv%) were calculated to assess rainfall fluctuations (Phan, 2005).

Metrics were processed by Excel 2010, SPSS 16.0, and XLSTAT 2021.2.2 software.

## Results and discussion

### Temperature

#### The maximum temperature

Between 2014 and 2020, the prevailing annual absolute maximum temperature in the Vietnamese Mekong Delta ranged from 35.2 °C to 37.6 °C (Fig. 2A). The observed highest annual absolute maximum temperature was 37.7 °C (on May 08, 2016 in Cang Long), 1.7 °C lower than such temperature in the Mekong Delta in the period of 1984–2013.

Typically, the monthly absolute maximum temperature in the Mekong Delta ranged from 33.5 °C to 37.4 °C. This temperature pattern showed a decrease from January to February, followed by a rapid increase during March and April. The monthly absolute maximum temperature reached its highest value in May and then gradually declined towards the end of the year due to the onset of the rainy season (May–November), reaching its lowest value in December (Fig. 2B).

The absolute maximum temperature in June–December tended to be higher than in the same months of 1984–2013. The monthly average maximum temperature during this period commonly ranged from +30.6 °C to +34.6 °C, reaching its highest values in April, and the lowest in January.

#### **The minimum temperature**

In the period of 2014–2020, the annual absolute minimum temperature in the Vietnamese Mekong Delta generally ranged from 17.1 °C to 20.8 °C (Fig. 3A). The observed lowest annual absolute minimum temperature was 16.7 °C (on January 23, 2014 in Cao Lanh), 0.9 °C higher than such temperature in the Mekong Delta in 1984–2013.

The Mann–Kendall test (M–K) result of  $S > 0$  for the trend of the absolute minimum temperature (Table 1) showed that the annual absolute minimum temperature tended to increase over time with a significance level of  $\alpha < 0.1$ . An Giang had the highest increase in the annual absolute minimum temperature and Vinh Long had the lowest increase by 3.50 °C and 1.87 °C respectively over the span of 7 years.

The monthly absolute minimum temperatures in the study area commonly ranged from 17.6 °C to 23.7 °C, with minimum values in January and highest in May (Fig. 3B). In 2014–2020, this parameter tended to reach higher values than in 1984–2013. The average minimum temperature was usually from 22.6 °C to 25.9 °C. Throughout the year, January had the lowest average minimum temperature and May had the highest one.

#### **Average temperature**

The air temperature of the study area was quite high. The annual average temperature in the period of 2014–2020 in the Vietnamese Mekong Delta was approximately 27.6 °C, which was 0.6 °C higher than the annual average temperature recorded from 1984 to 2013. The total annual temperature was approximately 10.068 °C, demonstrating stability with minimal variation across the years.

The annual average air temperature in the period of 2014–2020 was the highest at Chau Doc station in the upper reaches of the Vietnamese Mekong Delta (27.9 °C, which is 0.6 °C higher compared to the period of 1984–2013) and gradually decreased downstream, reaching a minimum at Cang Long station (27.2 °C, which is 0.4 °C higher than in 1984–2013). In 2016, 2019 and 2020, the average annual temperature was higher than in other years. These particular years also coincided with the highest global average temperature ever, of which 2016 is considered the hottest year due to the strong and prolonged El Nino activity (The climate summary announcement..., 2020, 2021). In 2014–2020, the lowest average annual temperature was recorded in 2014. (Fig. 4A).

**Table 1.** Results of the Mann–Kendall test for the annual absolute minimum temperature trend.

Station	M–K test value (S)	P-value	Sen's slope
Chau Doc	17.000	0.016	0.500
Cao Lanh	15.000	0.035	0.480
Vinh Long	13.000	0.072	0.267
Can Tho	13.000	0.072	0.440
Vi Thanh	15.000	0.035	0.300
My Tho	13.000	0.072	0.340
Cang Long	14.000	0.048	0.433
Soc Trang	19.000	0.007	0.367
Ba Tri	15.000	0.035	0.400

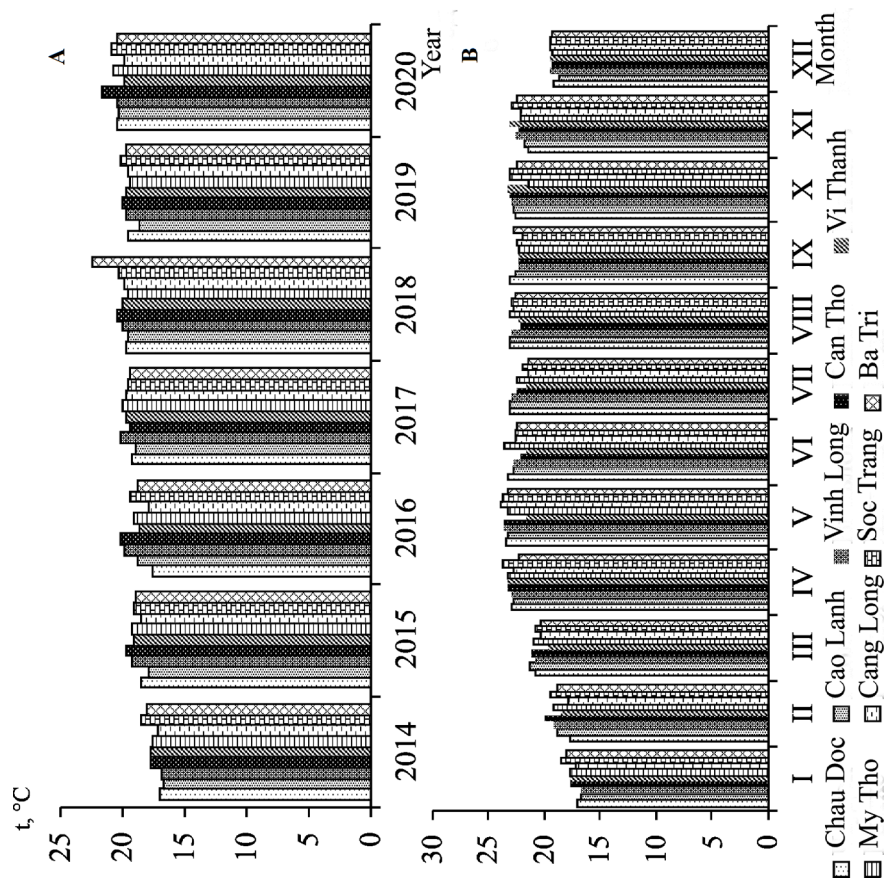


Fig. 3. **A** – annual absolute minimum temperature, **B** – monthly absolute minimum temperature in 2014–2020.

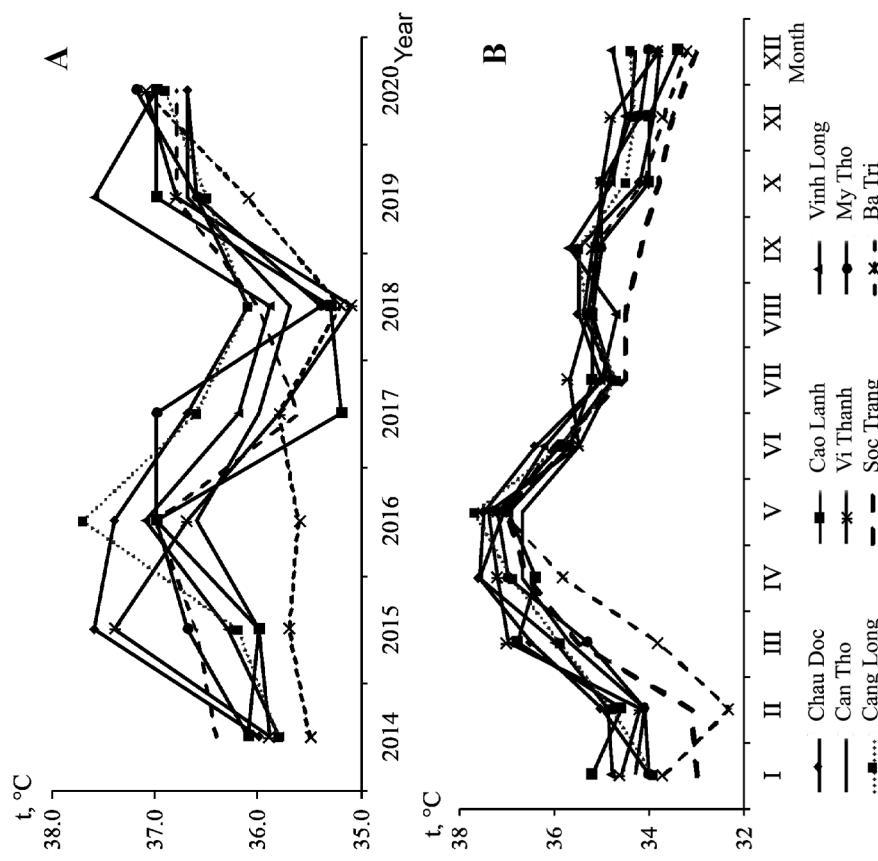


Fig. 2. **A** – annual absolute maximum temperature, **B** – monthly absolute maximum temperature in 2014–2020.



At 5 out of 9 weather stations, the M–K test for the trend of changes in the average temperature in the Vietnamese Mekong Delta (Table 2) gave the following results:  $S > 0$  and  $P < 0.1$ . This proves that from 2014 to 2020, the average annual temperature at Cao Lanh, Vinh Long, Cang Long, Soc Trang and Ba Tri stations tended to increase over time at a significance level of  $\alpha < 0.1$ . Over the span of 7 years, the rises in the average annual temperature in these provinces were 0.53 °C; 0.70 °C; 0.56 °C; 0.70 °C; 0.53 °C respectively.

The Vietnamese Mekong Delta has two distinct seasons: rainy season (from May to November); and dry season (from December to April) (Tran, 2013). The average temperature in the rainy season was higher than that in the dry season. The average temperature tended to increase gradually from February and peaked in April–May with the highest value of 29.5 °C (in Chau Doc, My Tho in May), then decreased rapidly in June–July. In November, the average temperature increased slightly, then decreased rapidly and reached a minimum in January with the lowest value of 25.8 °C at Vi Thanh and

**Table 2.** Results of the Mann–Kendall test for the annual average temperature trend (only stations with significant changes are indicated).

Station	M–K test value (S)	P-value	Sen's slope
Cao Lanh	13.000	0.065	0.075
Vinh Long	12.000	0.095	0.100
Cang Long	13.000	0.057	0.080
Soc Trang	12.000	0.095	0.100
Ba Tri	14.000	0.043	0.075

**Table 3.** The results of the Mann–Kendall test for the trend of the average temperature in the dry season.

Station	M–K test value (S)	P-value	Sen's slope
Chau Doc	14.000	0.048	0.200
Cao Lanh	17.000	0.016	0.220
Vinh Long	16.000	0.023	0.150
Can Tho	14.000	0.041	0.117
Vi Thanh	14.000	0.048	0.175
My Tho	15.000	0.031	0.140
Cang Long	14.000	0.048	0.133
Soc Trang	13.000	0.072	0.180
Ba Tri	18.000	0.010	0.167

**Table 4.** Average daily amplitude of temperature and annual amplitude of average temperature, °C.

Station	Amplitude	
	Daily	Annual
Chau Doc	7.7	3.8
Cao Lanh	7.2	3.9
Vinh Long	7.7	3.6
Can Tho	7.5	3.5
Vi Thanh	7.5	3.5
My Tho	7.3	3.8
Cang Long	8	3.5
Soc Trang	7.1	3.6
Ba Tri	6.9	3.7

**Table 5.** Daily amplitude of temperature, °C.

Station	Month											
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Chau Doc	8.0	8.5	9.7	9.0	8.2	7.2	7.3	7.0	6.6	6.8	6.9	7.4
Cao Lanh	7.9	8.0	8.7	8.2	7.9	6.7	6.9	6.7	6.4	6.2	6.1	6.8
Vinh Long	8.2	8.5	9.6	8.8	8.5	7.3	7.1	7.0	7.1	7.0	6.7	6.9
Can Tho	7.6	7.9	8.9	8.3	8.1	7.3	7.2	7.1	7.0	7.1	6.9	6.9
Vi Thanh	8.0	8.6	9.5	8.7	8.1	6.9	6.8	6.6	6.6	6.5	6.5	6.8
My Tho	7.6	7.4	7.7	7.8	8.1	7.2	7.2	7.1	7.1	6.9	6.8	7.2
Cang Long	8.3	8.3	9.4	9.0	8.6	7.5	7.6	7.6	7.5	7.5	7.4	7.7
Soc Trang	7.3	7.4	8.4	8.3	7.9	6.8	6.7	6.8	6.7	6.5	6.3	6.5
Ba Tri	6.6	6.2	6.8	7.1	7.8	7.3	7.5	7.4	7.3	6.6	6.0	6.5

Cang Long stations (Fig. 4B). The monthly average temperature in the period of 2014–2020 was higher than that in the period of 1984–2013. The Mann-Kendall test for the average temperature trend in the dry season (Table 3) showed that all the monitoring stations had M–K test results with values  $S > 0$  and  $P < 0.1$ . This demonstrates that the average temperature in the dry season tended to increase over time at a significance level  $\alpha < 0.1$ . The average temperature in the dry season had the highest increase in Cao Lanh with an increase of 1.54 °C over 7 years; and the lowest in Can Tho, with an increase of 0.82 °C over the same period.

The annual amplitude of average temperatures in the Mekong Delta ranged from 3.5 °C to 3.9 °C, the highest in Cao Lanh and the lowest in Can Tho, Vi Thanh and Cang Long. The daily thermal amplitude ranged from 6.9 °C to 8.0 °C, the lowest at Ba Tri station and the highest at Cang Long station (Table 4). Most stations had the highest daily thermal amplitude in April and the lowest in December. The daily thermal amplitude in the dry season was higher than that in the rainy season (Table 5).



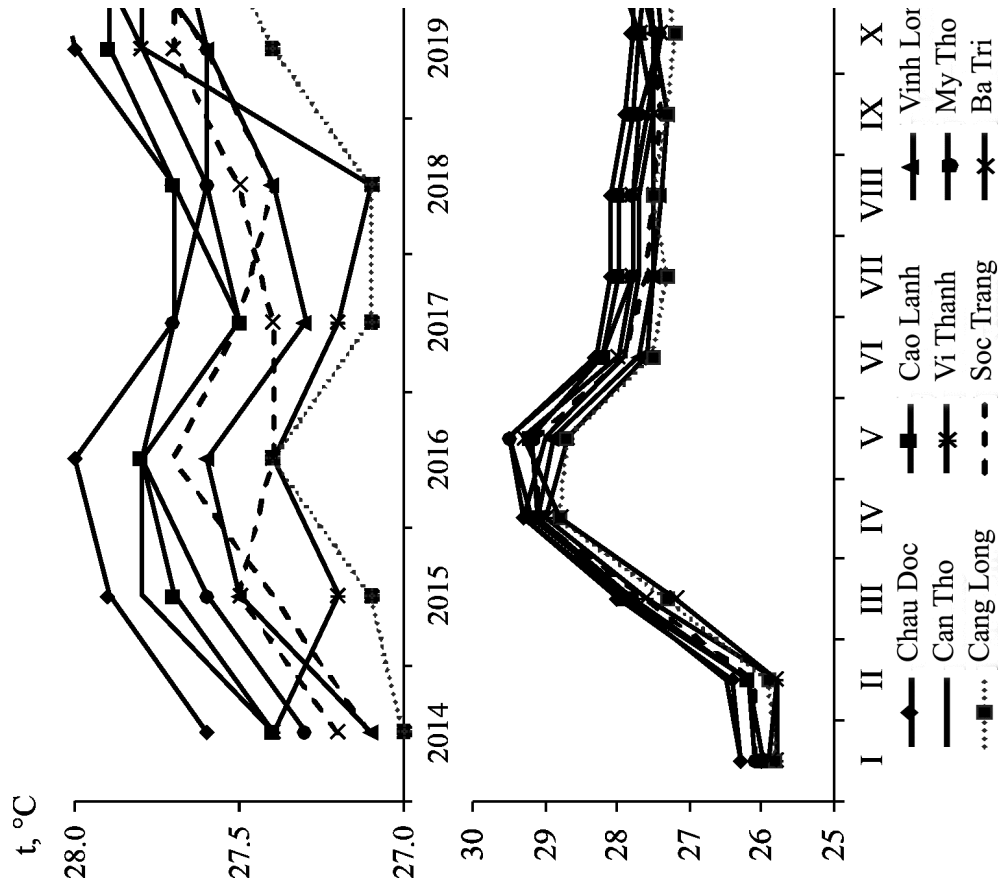


Fig. 4. **A** – annual average temperature, **B** – monthly average temperature in 2014–2020.

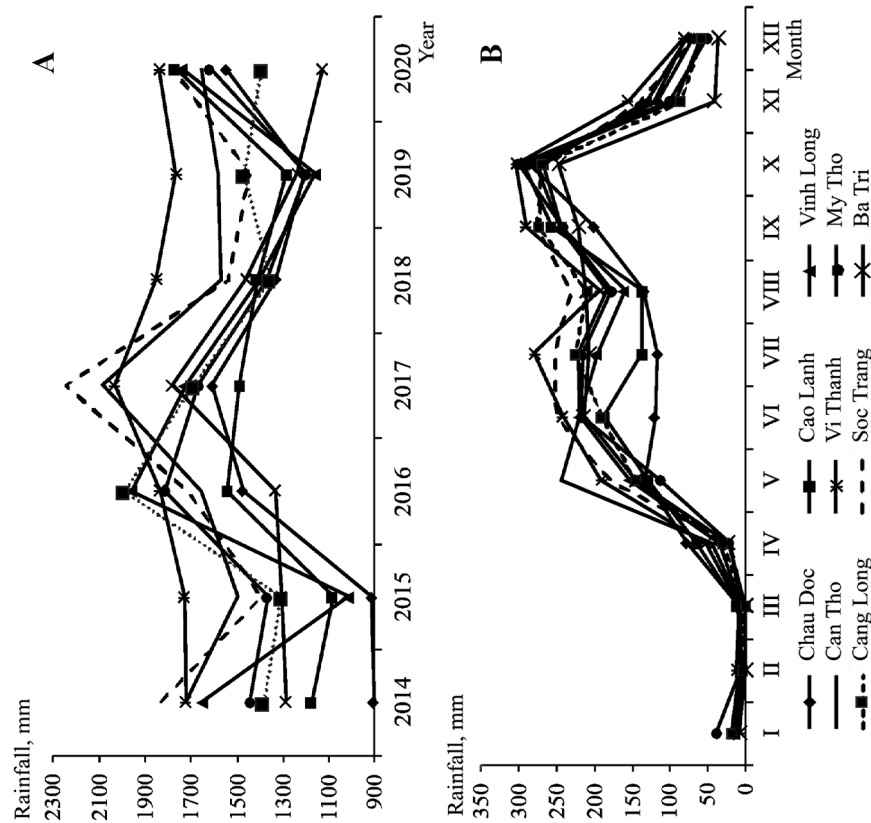


Fig. 5. **A** – total annual rainfall, **B** – total monthly rainfall in 2014–2020.

## Rainfall

### Distribution of annual rainfall

The Vietnamese Mekong Delta had abundant rainfall. In the period of 2014–2020, the total average annual rainfall for the study area was 1533.9 mm, 56.6 mm lower than the multi-year average (1984–2013). The total multi-year average annual rainfall (2014–2020) tended to be the lowest in the upper reaches of the Mekong Delta (1286.7–1397.3 mm), increased and reached the highest values in the central area (1499.7–828.9 mm) and then decreased slightly in the lower reaches (1365.1–1706.2 mm). The two provinces with the lowest annual rainfall were An Giang and Ben Tre.

In the period of 2014–2020, the annual rainfall was the lowest in 2015, while reaching its highest levels in 2016 and 2017. The recorded highest annual rainfall was 2247 mm (Soc Trang in 2017), and the lowest was 908.3 mm (Chau Doc in 2014) (Fig. 5A). In 2016, 2017 and 2020, rainfall tended to be higher than the multi-year average (1984–2013), whereas in other years of the period, this parameter was usually lower than the multi-year average.

Rain falls mainly in the rainy season, accounting for 86.56–94.75% of total annual precipitation. In 2015, 2018, 2019, during the rainy season, there was little rainfall; there was also very little precipitation in the dry season in the following years (2016, 2019, 2020), which resulted in severe drought and saltwater intrusion in the Mekong Delta (Nguyen, 2016; To, 2020). During the dry season, the lower delta of the Mekong River (Ben Tre, Soc Trang and Tra Vinh) generally received less rainfall than the upper delta.

In 2014–2020, the multi-year average number of rainy days in the Vietnamese Mekong Delta tended to be the lowest in the upstream area (130–149 days), increased and reached the highest in the central area (142–166 days), then decreased slightly in the downstream area (136–158 days). The lowest annual number of rainy days recorded was 95 days (Chau Doc in 2015) and the highest was 201 days (Vi Thanh in 2017). On average, nearly 88% of rainy days per year had rainfall below 25 mm per day; 2.63% of rainy days had rainfall over 50 mm/day (heavy rain), the days with rainfall over 100 mm/day (very heavy rain) rarely occurred – only 0.17%. The highest daily rainfall in the period of 2014–2020 was 171.2 mm (observed on August 26, 2016 in Ba Tri).

### Distribution of monthly rainfall

Total monthly rainfall fluctuated quite obviously during the year. From June to October, the rainfall was high, with monthly rainfall from 118 mm to 304.4 mm. The highest rainfall was in October (accounting for 15.82–22.26% of annual rainfall). From November to December, the rainfall gradually decreased (37.1–156.6 mm) and the dry season began.

In the dry season, rain rarely occurred. From January to March, the monthly rainfall ranged from 0.6 mm to 39.3 mm. The lowest rainfall usually occurred in March (accounting for 0.04–0.82% of annual rainfall). The lowest monthly rainfall was observed in Soc Trang and Ba Tri (0.6 mm). In April and May, the rainfall increased markedly (21.8–244.3 mm), followed by the rainy season (Fig. 5B). The rainfalls in March–May, July–August, and November tended to decrease compared to the same period of 1984–2013.

The Mekong Delta during the rainy season is characterized by long periods with little or no rainfall, resulting in drought (known as “Ba Chan” drought). Such drought occurs when it is rainless for at least 5 consecutive days or the rainfall is less than half of the total amount of evaporation (Hoang, 2015).

“Ba Chan” drought greatly affects agricultural production and daily life. In the period of 2014–2020, in An Giang, Dong Thap and Hau Giang provinces, there were 4 to 6 droughts per year on average, sometimes 8–9. Other provinces had an average of 2 to 3 droughts per year, sometimes 6–8. Most of the droughts (80%) lasted 5–7 days, 15% – 8–10 days and 5% – more than 10 days. In 2014–2020, the longest period without rain was 16 days; it was recorded in Chau Doc from August 01 to August 16. Droughts occurred almost every month during the rainy season; most often in August with a frequency of 24%.

In the period 2014–2020, there is a consistent similarity in the number of monthly rainy days between the peak months of the rainy season (from June to October). From June to October, Chau Doc station had a slightly lower number of monthly rainy days than other stations but also from 15 days or more. Meanwhile, at the remaining monitoring stations, the number of monthly rainy days in the multi-year

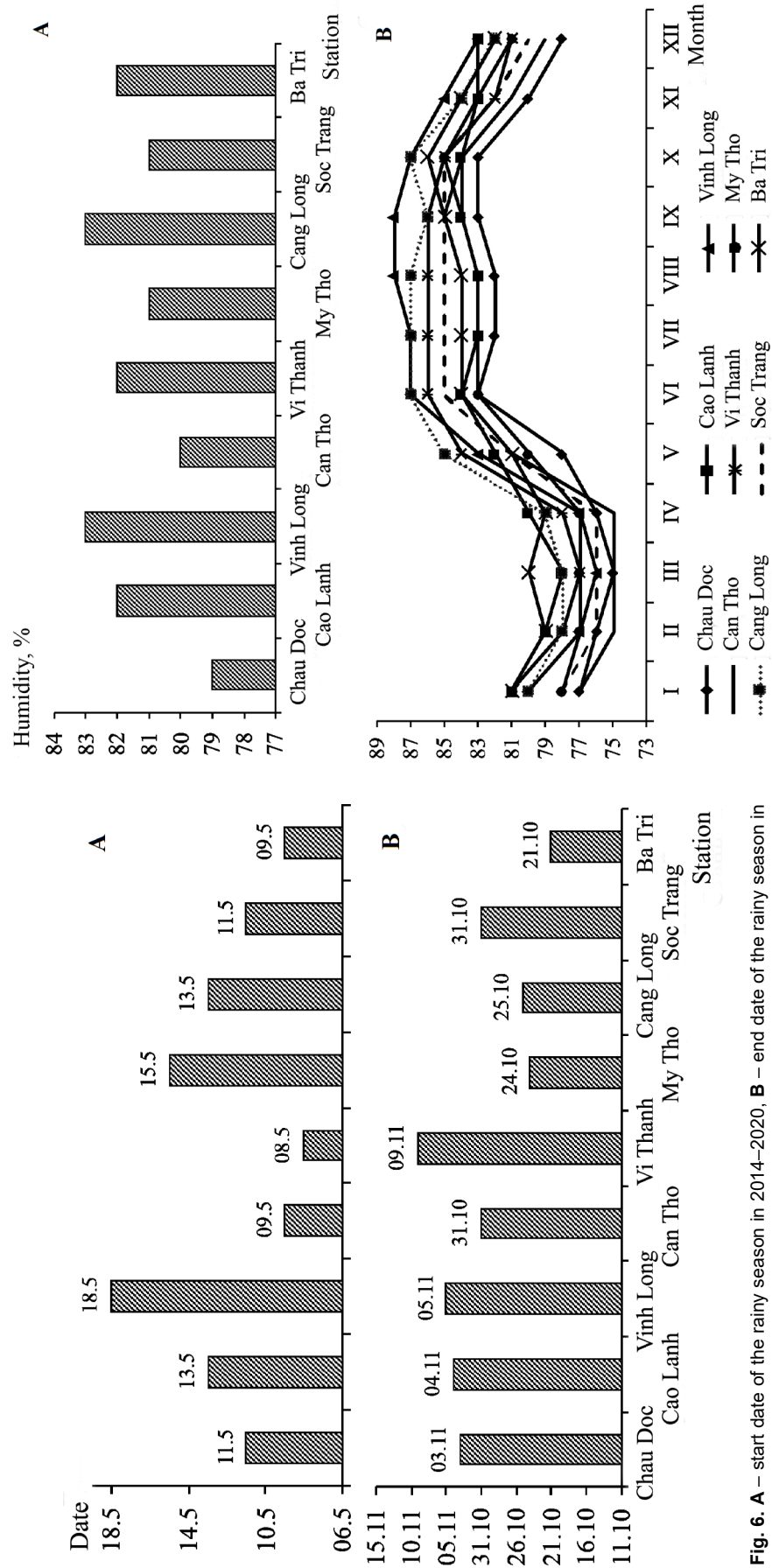


Fig. 7. **A** – annual average air humidity in 2014–2020, **B** – monthly average air humidity in 2014–2020.

Fig. 6. **A** – start date of the rainy season in 2014–2020, **B** – end date of the rainy season in 2014–2020.

average was usually from 20 to 23 days; the highest number of monthly rainy days was 24 days (in June, July and August in Soc Trang). February and March had the lowest number of rainy days and were considered the two stable months of the dry season. The remaining months of the year (January, April, May, November, and December) exhibited considerable variations in the number of rainy days, in accordance with the law of seasonal transitions.

#### **Variability of the start and end dates of the rainy season**

Throughout the period of 2014–2020, the onset of the rainy season in the Vietnamese Mekong Delta commenced in the first half of May. The rainy season started at the earliest in Vi Thanh (on May 08) and at the latest in Vinh Long (on May 18) (Fig. 6A), later than the start of rainy season in the period of 1984–2001 (May 03–May 12) (Le, 2002). The earliest onset of the rainy season during the study period was observed in 2017 (between late April and early May), and the latest – in 2015 (from the second half of May to early June).

The rainy season tended to end at the end of October until the first 10 days of November, earlier than the multi-year average of 1984–2001 (November 09 – December 10) (Le, 2002). The latest end date of the rainy season (November 09) was recorded at Vi Thanh station, the earliest – at Ba Tri station (October 21) (Fig. 6B). Therefore, the rainy season tended to shorten compared to the period of 1984–2001.

#### **Fluctuations in the rainfall**

The standard deviation of annual rainfall in the Vietnamese Mekong Delta was from 106 mm to 341 mm depending on the region, equivalent to a coefficient of variation of 0.06–0.22. It showed that in 2014–2020 the annual rainfall didn't fluctuate much. However, the rainfall in the dry months fluctuated sharply compared to the average for the same period of many years. The rainfall was most subject to change in February and March with a coefficient of variation from 1.37 to 2.65. In the rainy season, the rainfall was quite stable, less variable than in the dry season, with the greatest coefficient of fluctuation at only 0.43–0.72. In June and July, the amount of precipitation, as a rule, fluctuated less from year to year (Table 6).

#### **Air humidity**

The Vietnamese Mekong Delta had an average air humidity of 79% or more in the period of 2014–2020, which was fairly uniform across the region (Fig. 7A). The highest annual average air humidity (recorded in Vinh Long in 2017 and in Cang Long in 2018) was 85%. The monthly average humidity was 75% or more.

The humidity in the rainy months was higher than that in the dry months. The monthly average humidity in the dry season commonly ranged from 75% to 81%. Months from February to April had the lowest average humidity of the year, with the lowest at 75% (in Can Tho from February to April and in Chau Doc in March). In the rainy season, the monthly average humidity was usually from 81% to 88%. September and October had the highest average humidity of the year, with the highest at 88% (in Vinh Long in September). These were also the month with the highest rainfall of the year (Fig. 7B).

There were frequent occurrences when the humidity levels dropped below 50%, and in some cases even to 30%. In particular, in Can Tho, My Tho and Cang Long, the lowest humidity recorded during the years 2014–2020 dropped even lower than in the period from 1984 to 2013 (Fig. 8).

### **Evaporation**

#### **Total evaporation**

The total annual evaporation in the Vietnamese Mekong Delta during the period from 2014 to 2020 was 942.3 mm (61.4% of the total annual rainfall), 60.3 mm lower than that in the period of 1984–2013. The multi-year (2014–2020) average annual evaporation was the highest in Vinh Long (1041.5 mm) and the lowest in Vi Thanh (838.9 mm).

At most weather stations, the maximum annual evaporation was recorded in 2015 (it was also higher than the multi-year average for 1984–2013), and the minimum – in 2017. The highest annual evaporation was 1336.9 mm (Vinh Long in 2015), whereas the lowest was 722.1 mm (Vi Thanh in 2017) (Fig. 9A). The evaporation in the dry season was higher than in the rainy season. The peak evaporation occurred in March, ranging from 92.1 mm to 116.5 mm while the lowest evaporation was recorded in October, ranging from 51.6 mm to 67 mm. The fluctuation in evaporation during the year was inversely proportional to rainfall, leading to extended dry periods in the dry season (Fig. 9B). The multi-

**Table 6.** Standard deviation (S) and coefficient of variation (Cv) of monthly and annual rainfall.

Station	Characteristic	Month												Year
		I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
Chau Doc	S	19	13	12	50	58	46	52	66	102	132	49	50	288
	Cv	1.59	2.65	1.37	0.64	0.43	0.38	0.44	0.48	0.51	0.46	0.42	0.73	0.22
Cao Lanh	S	26	14	20	56	54	70	63	69	144	70	55	49	235
	Cv	1.60	2.18	1.74	0.87	0.42	0.37	0.46	0.50	0.56	0.24	0.58	0.83	0.17
Vinh Long	S	24	20	18	45	103	104	59	53	81	100	94	54	341
	Cv	1.73	1.87	2.18	1.24	0.67	0.47	0.30	0.33	0.33	0.37	0.72	0.70	0.22
Can Tho	S	37	21	17	33	129	49	45	85	95	78	29	54	193
	Cv	1.95	2.47	1.98	0.73	0.53	0.22	0.20	0.46	0.38	0.28	0.24	0.67	0.11
Vi Thanh	S	8	29	16	37	64	77	77	83	86	125	36	54	106
	Cv	0.88	2.29	1.62	0.70	0.34	0.31	0.27	0.43	0.29	0.41	0.23	0.66	0.06
My Tho	S	42	17	21	34	54	59	77	48	108	106	46	40	211
	Cv	1.08	2.61	2.65	1.54	0.48	0.27	0.35	0.27	0.44	0.35	0.45	0.77	0.14
Cang Long	S	16	10	2	33	89	48	65	104	94	96	32	38	245
	Cv	0.91	2.60	1.92	1.11	0.61	0.25	0.29	0.50	0.34	0.35	0.37	0.66	0.16
Soc Trang	S	15	12	1	29	96	63	101	27	66	104	66	65	290
	Cv	1.43	2.56	2.43	1.31	0.54	0.25	0.40	0.12	0.24	0.38	0.47	0.96	0.17
Ba Tri	S	11	3	2	21	86	51	37	86	72	102	22	36	211
	Cv	1.28	2.65	2.65	0.87	0.60	0.23	0.18	0.40	0.32	0.41	0.52	0.96	0.15

year average daily evaporation in 2014–2020 ranged from 2.3 mm to 2.9 mm, with minimal regional differences. The highest recorded daily evaporation was 7.8 mm (Soc Trang, on February 28, 2017).

#### **Drought index**

To assess drought conditions in the study area, we used drought index K (Nguyen, 1995). The drought index K was determined as follows:

$$K = E/R$$

where R is rainfall and E is evaporation.

The calculation of the drought index in the Vietnamese Mekong Delta showed that its annual value was less than 1 and ranged from 0.5 to 0.8 (Fig. 10A). This indicates the area has a predominantly humid climate, where water is generally abundant (Le and Nguyen, 2008). However, there were notable differences in drought conditions between months of the year as well as between various geographical regions. All rainy months had a drought index < 1 (except for November in Ba Tri with a drought index of 1.7 – shown at a slightly dry level). In the dry season (except for December in Vi Thanh with a drought index < 1), at all the meteorological stations, a drought indexes ≥ 1 was recorded, with values from 1.0 to 192.5 (Fig. 10B). This demonstrates that in the dry season, the Vietnamese Mekong Delta faced varying degrees of water scarcity and drought. The levels of drought in the dry season were from slightly dry to very dry. The most intense drought typically occurred in February and March in the downstream provinces of the Vietnamese Mekong Delta.

#### **Hours of sunshine**

In the period of 2014–2020, the total annual hours of sunshine, average for the study area, was 2521 hours, with the lowest recorded in Vi Thanh (2248 hours) and the highest observed in Can Tho (2654 hours). Chau Doc, Cao Lanh, Can Tho, My Tho, and Soc Trang stations had higher multi-year

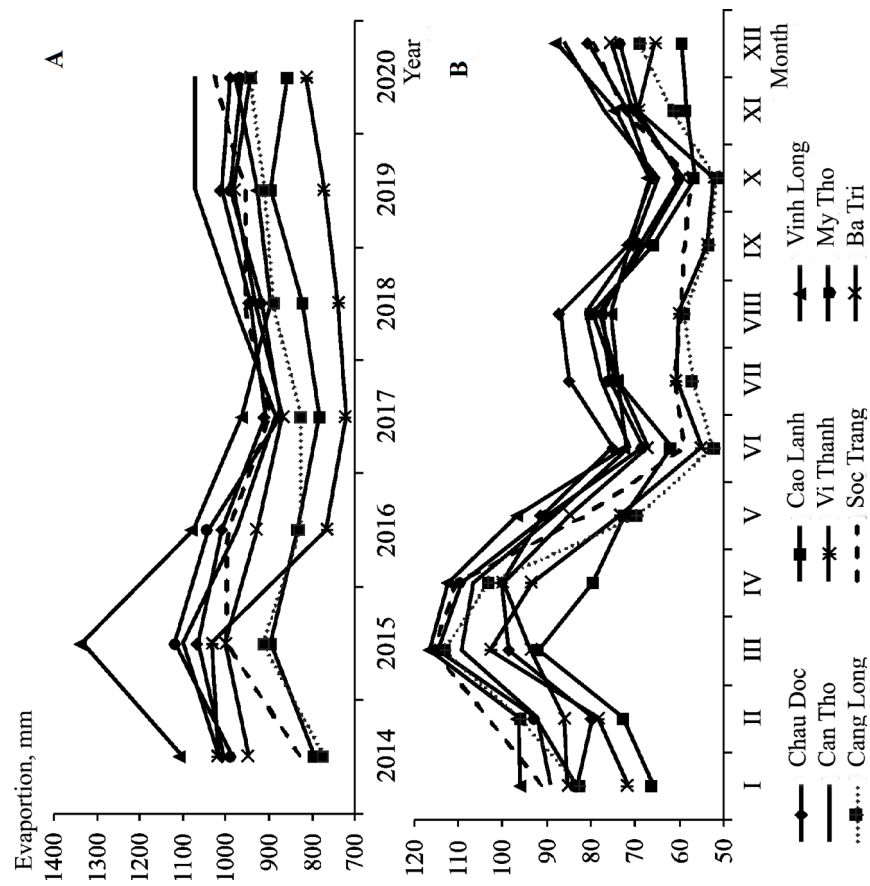


Fig. 9. **A** – annual evaporation, **B** – monthly evaporation in 2014–2020.

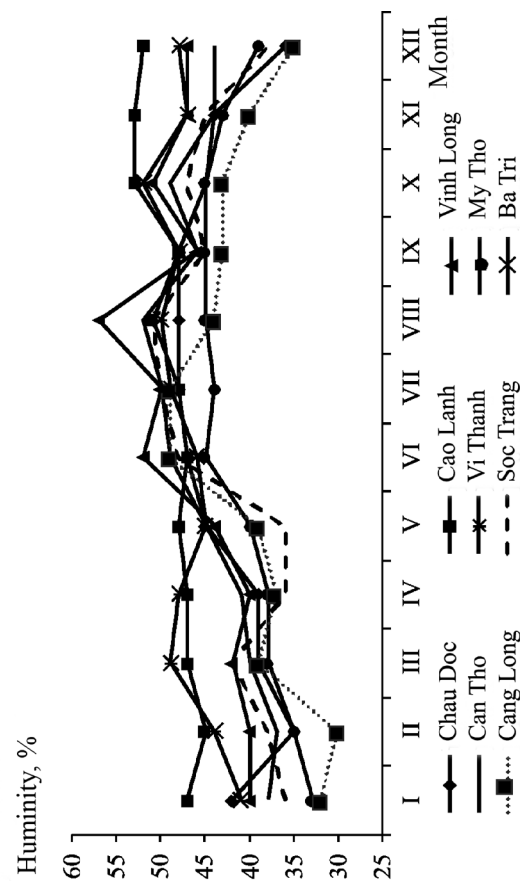


Fig. 8. Monthly absolute minimum air humidity in 2014–2020.

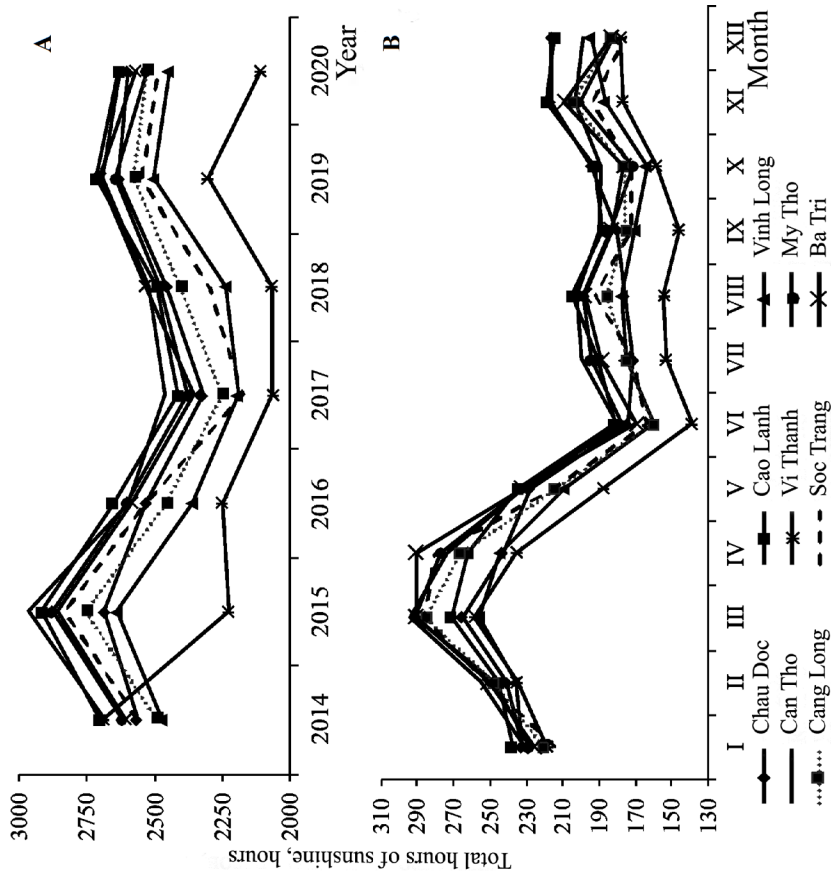


Fig. 11. **A** – total annual hours of sunshine, **B** – total monthly hours of sunshine in 2014–2020.

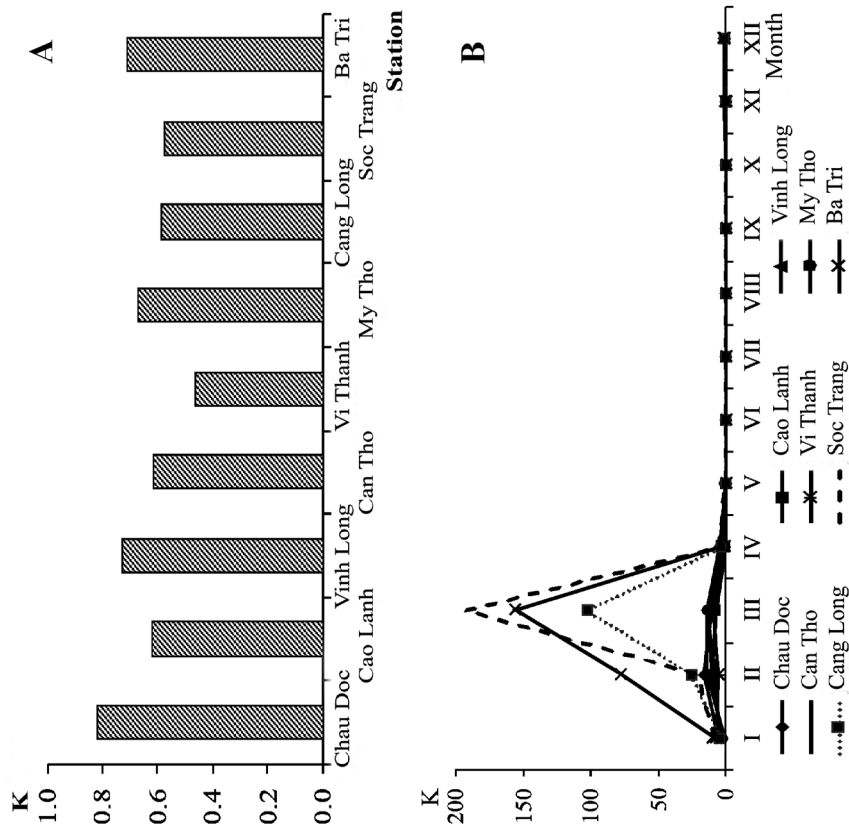


Fig. 10. **A** – rannual drought index, **B** – monthly drought index in 2014–2020.



(2014–2020) average annual sunshine hours total than those during the period of 1984–2013. The total annual sunshine was the highest in 2015, and the lowest in 2017. The highest annual sunshine was up to 2963 hours (Can Tho in 2015), and the lowest was 2068 hours (Vi Thanh in 2017) (Fig. 11A).

The dry season received a higher number of sunshine hours compared to the rainy season, with monthly sunshine ranging from 176 to 294 hours, with an average of 6–10 hours of sunshine per day. In contrast, the rainy season had monthly hours of sunshine ranging from 140 to 235 hours, with an average of 5–8 hours of sunshine per day. March and April had the highest monthly number of sunshine hours, while June had the lowest monthly sunshine hours of the year (Fig. 11B).

## Conclusion

In the Vietnamese Mekong Delta, the average annual temperature and sunshine in 2014–2020 were higher than in 1984–2013. At the same time, the total annual rainfall and the total annual evaporation were lower than in 1984–2013.

The rainy season typically began in the first half of May and extended until the end of October or the first 10 days of November. The rainy season had a higher average temperature, more rainfall, higher humidity, lower evaporation, and lower hours of sunshine than those in the dry season. From January to March, the Vietnamese Mekong Delta faced a very serious drought.

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