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TEMPORAL DISTRIBUTION PATTERN OF PRECIPITATION AND METEOROLOGICAL DROUGHT INDICES IN THE MONSOON TROPICAL REGION OF THE SOUTHEAST VIETNAM

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Short title

VIETNAM METEOROLOGICAL DROUGHT INDICES

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ABSTRACT

The choice of meteorological drought monitoring indices strongly depends on the regional conditions. The Southeast Vietnam has specific precipitation regime and complicated drought conditions. In this study, we presented the temporal distribution of precipitation and evaluated several meteorological drought indices in 35 stations and among 32 years (1978 - 2009) in this area. For the precipitation regime, the results show that the Southeast Vietnam has an abundant precipitation, but not well temporally distributed through the year. Precipitation occurs in the rainy season from May to October and equals more than 80% of the annual rainfall amounts. The seasonal drought not only happens during the no-rainy season, but the short drought also occurs within the rainy season due to the precipitation decreases 70 - 90% of the monthly rainfall amounts. The seven meteorological drought indices including Deciles Index (DI), Relative Precipitation Index (RPI), Statistical Z-score (Z-score), China Z Index (CZI), Aridity Index (AI), De Martonne Aridity Index (I) and Standardized Precipitation Index (SPI) are compared on the basis of specific characteristics of drought in this region. The results indicate that DI, RPI, Z-score, CZI, AI and I can reflect the specific characteristics of meteorological drought in the Southeast region. For the long-lasting drought, the long-time scales SPI reflected the precipitation situation well. However, the SPI failed to describe realistically drought at short scales. The results suggest that the precipitation-based drought indices (DI, RPI,

Z-score and CZI) can be used to assess and monitor meteorological drought in the Southeast Vietnam.

KEY WORDS: Drought; Vietnam; Precipitation; Monsoon; Meteorological drought index; Precipitation-based drought index; Standardized Precipitation Index

1. INTRODUCTION

Drought is one of the major natural hazards around the world and one of the most complex but least understood of all natural hazards. Drought is a sustained, extended deficiency in precipitation and is often associated with other climatic factors (Bogardi et al., 1994). Drought can be grouped by type as follows: meteorological, hydrological, agricultural and socioeconomic (Wilhite and Glantz, 1985). There are clearly strong relationships between the four types of drought. Meteorological drought is principally defined by the deficiency of precipitation from expected or "normal" amount over an extended period of time. This type of drought is focused on the physical characteristics of drought, i.e., the departure of precipitation from normal, rather than on the impacts associated with this departure. The beginning and ending of meteorological drought may be a significant sign of all kinds of drought. A meteorological drought is translatable to hydrological, agricultural and socioeconomic drought. Therefore, meteorological drought index is important for drought assessment and monitoring.

Numerous meteorological drought indices have been developed to date. Most meteorological drought indices are based on precipitation: *Relative Anomaly Index* (Rooy, 1965), *Decile Index* (Gibbs and Maher, 1967), *Standardized precipitation Index* (McKee et al., 1993), *Drought Severity Index* (Bryant et al., 1994), *Statistical Z-score* (Triola, 1995), *Effective Drought Index* (Byun and Wilhite, 1999), *China-Z Index* (Wu et al., 2001), *Relative Precipitation Index* (Bąk and Łabędzki, 2002). There are also some recursive indices, such as *Fooley anomaly index* (Foley, 1957), *Bhalme and Mooly Drought Index* (Bhalme and Mooly, 1980). In general, these meteorological drought indices have their advantages, for example, easy to measure, accurate statistical measurement of departure from normal, good tools to define, detect and monitor drought. However, they have many weaknesses: based on precipitation only, valid only for specific application in specific region, requiring a long data record to get accurate calculations. Therefore, there are other precipitation, evaporation and temperature-based drought indices.

Some meteorological drought indices are based on remotely sensed parameters, while the aforementioned indices are derived using station-based measurements. Although station-based indices can provide accurate point estimates of drought conditions, their accuracy and level spatial details are a function of the density and distribution of the station network. Large numbers of drought indices provide somewhat different measure of drought (Heim, 2002), but none of the major indices is inherently superior to the rest in all circumstances. Hence, the choice of monitoring drought index in a specific area strongly depends on ours requirements and the evaluation of drought index at the local environmental conditions.

Vietnam is situated in a monsoon tropical climate zone. With a special geographic locality and monsoon, together with the differentiation of rain, the drought in Vietnam appears complicatedly. In general, drought happens in most regions of the country and occurs frequently. Drought can occur even in the rainy season or form a chain of successive events. Historically, droughts have been localized and seasonal, but they have become a more serious problem in recent years (Binh, 2004; Thuc, 2009). Because of the complexity of drought and the specific temporal characteristics of precipitation in this area, the study about drought indices is really necessary for drought monitoring and assessment in this area. Up to now, however, there are limited drought studies in Vietnam. For example, using a *K index,* Hieu (2002) evaluated the characteristics and mapped the distribution of drought, and he also evaluated its effects in Vietnam. Using the *SPI,* the authors showed characteristics of temporal and spatial meteorological drought distribution (Tinh, 2006; Thang, 2007). They used the *Surface water supply index* (SWSI) to identify hydrological drought for drought prediction and resistance in the Vietnamese central highlands. Other researchers investigated some aspects of the recent droughts in the Mekong region and tried to establish their likely causes and how such incidents could best be mitigated (Huy and Rajib, 2009; Thuc, 2009). The existing researches have obtained some significant results. However, limited attentions are given to the drought indices in the particular region and complicated appearance of drought due to a specific precipitation temporal characteristics requires evaluation of meteorological drought indices in this area.

The aim of this study is to analyze the temporal distribution pattern of precipitation and compare several meteorological drought indices in the monsoon tropical region of the Southeast Vietnam.

2. MATERIALS AND METHODS

2.1 Study area

The Southeast Vietnam region is located in 10°20'-12°20'N, 105°80'-107°60'E. It is surrounded by Cambodia to the North and the West, Central Highlands to the Northeast, South Central Coast to the East, East Sea to the Southeast and the Mekong basin to the Southwest. This region, as shown in Fig.1, includes five provinces (Dong Nai, Binh Duong, Ba Ria-Vung Tau, Binh Phuoc, Tay Ninh) and one municipality Ho Chi Minh. With total land area of 2,360.52 km^2 and population of 14,095.7 thousands, this region is the most economically developed region in Vietnam. The Southeast Vietnam has a tropical monsoon climate with high solar radiation, humidity and temperature throughout the year. The mean annual temperature is about 26°C and changes a little. The air humidity is high:

the average annual humidity is about 78 to 83 %, the total sunny hours are around 2,000 to 3,000 h and the solar radiation annually received is in average of 140 - 160 Kcalcm^{-2} (Lap, 2003; General Statistics Office of Vietnam, 2010).

The Southeast Vietnam region is characterized by strong Southwest monsoon from March to October. This Southwest monsoon wind system, saturated with water, causes a lot of rainfall (annual rainfall ranges from 1400 to 2700 mm) and establishes the rainy regime in this region. The rainfall concentrates in the rainy season from early May to October (monthly rainfall amount more than 193 mm) whereas the dry season is from December to March with a negligible precipitation. The seasonal drought always happens during the no-rainy season every year. Under the influence of unstable Southwest monsoon, and further because of the complicated topography, the seasonal drought in the Southeast Vietnam always fluctuated, between the years. Therefore, the evaluation of drought indices is necessary for drought monitoring in this region.

2.2 Data and methods

Monthly precipitation data from 35 precipitation stations and other monthly meteorological parameters (potential evaporation and temperature) from five weather stations covered (Fig.1) the Southeast Vietnam region were used. The monthly data at these stations is from 1978 to 2009 (32 years).

The Deciles Index (DI), Relative Precipitation Index (RPI), Statistical Z-score (Z-score), China Z Index (CZI), Standardized Precipitation Index (SPI), Aridity

Index (AI) and De Martonne Aridity Index (I) were calculated and compared. The short descriptions of the seven drought indices are given in the appendix. We used the program that calculated SPI proposed by the National Drought Mitigation Center, University of Nebraska-Lincoln, United States. Other drought indices were computed by Microsoft Visual Basic program. The Pearson correlation coefficient was used to evaluate the correlation between the drought indices.

3. RESULTS

3.1 Temporal distribution pattern of precipitation and meteorological drought

The Southeast Vietnam has a tropical monsoon climate and basically two seasons: wet and dry. The precipitation regime is mainly dominated by the Southwest monsoon. The interaction between the Southwest monsoon and the topography plays a big role in the precipitation patterns in this area. The Southwest monsoon wind system starts blowing from the Indian Ocean, providing a main rainfall of this region and this wind system also determines characteristics of drought indirectly in this region (Lap, 2003).

In the Southeast Vietnam, the annual rainfall ranges from 1400 to 2700 mm. The yearly amount of precipitation is abundant, but it is not well temporally distributed throughout the year, and only concentrated in the rainy season from early May to October (monthly rainfall amount more than 193 mm). On the other hand, the dry season is from December to March with a negligible amount of precipitation (monthly rainfall amount less than 30 mm) (Table 1 and Fig. 2). The rainfall concentrates during the rainy season and equals more than 80% of the annual rainfall amount. Specially, though rainfall concentrates in the rainy season, the short drought also happens in this period as precipitation decreases 70 - 90% of the monthly rainfall amount. For example, the short drought in the rainy season occurs in August 1979 (Fig. 3). As discussed above, the Southeast Vietnam region is characterized by strong Southwest monsoon influences. Therefore, the basic temporal characteristics of drought in this region is that drought happen seasonally. The seasonal drought happens during the no-rainy season from December to March. The dry and wet seasons' characteristics of the precipitation regime have a significant effect on evaluating and using drought index.

In this region where the solar radiation, humidity and temperature are high and little changed during most of the year, the specific temporal precipitation distribution has major effect on the annual crop. Further, in this area, the growing season begins when the rainy season starts, so precipitation may be a major effect on the length of the growing season. Although the period of drought that happens during the growing season of the annual crop is short (such as in August, 1979, at Tay Ninh station, Fig. 3), it affects significantly on the crop. So it is necessary to evaluate the drought indices to give valuable information of duration and severity of drought.

3.2 Comparison of seven meteorological drought indices

The correlation coefficient values between RPI, Z-score, CZI and precipitation (shown in Table 2) almost equal 1. These values present that these drought indices have a strong relationship at any time scale. These drought indices indicate the precipitation situation well and can detect drought at any time scale (Fig. 3 and Fig. 4). However, the correlation coefficient values vary greatly for the SPI at different time scales. On 12- and 24-month time scales, SPI has a high correlation with the precipitation, R^2 is larger than 0.9831 (Table 2). On the contrary, on 1-, 6-, 9-month time scales, SPI has a poor correlation with precipitation, R^2 less than 0.4022 (Table 2). These results show that the SPI is only highly correlated with precipitation at large-time scales in the present research area. As well it reveals that the SPI has weaknesses when it be used to estimate the precipitation situation at short-time scales.

The SPI is widely accepted and used throughout the world in both research and operational modes because it is normalized to a location and in time. This standardization allows the SPI to determine the rarity of a current drought event, as well as the probability of the precipitation necessary to end the current drought (McKee et al., 1993). In this study, the same relationship between SPI and precipitation, on 12- and 24-time scales, SPI has a high correlation with the other precipitation-based drought indices, R^2 is larger than 0.9778 (Table 3). However, on 1-, 3-, 6- and 9-month time scales, SPI has poor correlation with precipitation-based drought indices, R^2 is less than 0.4022 (Table 3). Besides, the linear regression between SPI and other precipitation-based drought indices is shown in Fig. 5. It's obvious that the SPI, is highly correlated with other indices at large-time scales for this research area.

Unlike precipitation-based drought indices, AI is calculated by precipitation and potential evaporation. Table 4 and Fig. 6 show that all precipitation-based drought indices have a good correlation with AI except SPI at short-time scales. The R^2 between AI and CZI, Z-score, RPI and DI is larger than 0.6932 at any time scale. It is evident that the correlation is closed for this specific study area except SPI at short-time scales.

De Martonne Aridity Index (I) is the monthly precipitation amount and monthly mean air temperature-based drought index. Except SPI at short-time scales as expected, again, all precipitation-based drought indices (CZI, Z-score, RPI and DI) have a close correlation with the precipitation and temperature-based drought index (I), R^2 is larger than 0.9742 (Fig. 7).

4. DISCUSSIONS

The results represent that DI, RPI, Z-score and CZI have the similar results, reflecting the precipitation situation well for all time scales. These drought indices are appropriate to define, detect and monitor meteorological drought in the Southeast Vietnam. The findings of our study are in agreement with Wu et al. (2001), Morid et al. (2006). The results show that there are good correlations between the other climatic parameters-based drought (AI and I) and precipitation-based drought indices (DI, RPI, Z-score and CZI). It is not surprising because we are aware that the Southern Vietnam has a tropical climate (hot and wet most of the year) (Huy and Chinh, 2007). The temperature and potential evaporation change little in this area. The mean annual temperature is about 26°C throughout this region; the difference between the mean monthly minima and maxima is only about 5°C (Fig. 2). Precipitation is an important factor for calculating meteorological drought indices anywhere in the world. Particularly, the temperature and potential evaporation has little changes throughout the year whereas the precipitation changes is very large (characterized by distinct wet and dry seasons). So precipitation becomes a very crucial factor while temperature and potential evaporation are slight effective parameters when evaluating meteorological drought indices in this region. In addition, compared with the relationship between the AI and DI, RPI, Z-score, CZI, the I index has a closer correlation with DI, RPI, Z-score, CZI, due to the fact that the temperature change less than the potential evaporation (shown in Fig. 2). In such fact, potential evaporation is the second important factor, while temperature is the least influential factor for estimating meteorological drought indices in this region. It may be peculiar for the Southeast Vietnam region which has a monsoon tropical climate.

In the Southeast Vietnam, the temperature, potential evaporation and precipitation-based drought indices have good correlations with the precipitation-based drought indices; therefore these precipitation-based drought indices represent meteorological drought indices. However, the seasonal drought characterized by zero-precipitation during December to March, and the short-term drought occurring in the rainy season might influence on the precipitation-based indices, which obtained at short-time scales. SPI is used by almost all national meteorological and hydrological services around the world. SPI can provide similar results to the precipitation-based drought indices for all time scales in some regions in the world. But with the specific temporal distribution pattern of precipitation in the Southeast Vietnam, this study results indicate that SPI can provide similar results to the precipitation-based drought indices only on the large-time scales. In the Southeast Vietnam, we found a limit on short-time scales. The rainfall is abundant in the Southeast Vietnam, but it concentrated in some months in wet season from early April to November. In the other hand, in the dry season, from December to March, and zero rainfall values are common (Table 1 and Fig. 2). In such situation, the SPI at short-time scales referring to non-normally distributed, over estimates and fails to indicate a drought occurrence. The results in this paper provide evidence that the SPI at short-time scales (1- ,3- ,6- and 9- month) may be not be useful for the applying in the Southeast Vietnam. These results are different from the previous study results in other regions around the world for example, Wu et al. (2001) in China, Morid et al. (2006) in Iran, Łabedzki L. (2007) in Poland. In contract, our results are consistent with some previous findings in other regions in the world for example, Hayes et al. (1999); Wu et al. (2007) in the United States, Kim et al. (2009) in

South Korea, Kumar et al. (2009) in India, Zhai and Feng (2009) in China. These results are important for applying SPI in Vietnam. Because there are some authors (Tinh ND, 2006; Thang, 2007) used SPI to measure the meteorological drought and give early drought warning in Vietnam. So in this region, SPI may be suitable only to long-term time scale drought. Morid et al. (2006) and Kim et al. (2009) confirmed that the Effective Drought Index (EDI) was more efficient than the SPIs in assessing both short and long-term droughts in Iran and South Korea, respectively. This establishment needs to be investigated to apply the EDI in the Southeast Vietnam. It's interesting from our finding, we suggest that could be a topic to study the EDI in further.

5. CONCLUSIONS

This study examined not only the precipitation-based drought indices but also the potential evaporation, temperature-based drought indices. The results of this study indicate that:

* The specific temporal precipitation distribution and complicated drought conditions in this region have effects on evaluating and using drought index.

* With the particularity of the monsoon tropical region of the Southeast Vietnam, the precipitation-based drought indices (DI, RPI, Z-score and CZI) provide similar results to the other climatic parameters and precipitation-based drought indices for all time scales and can be used to monitor and assess drought in this area.

* With the specific precipitation temporal characteristics in the Southeast Vietnam, SPI at short-time scales may not be accurate to indicate a drought occurrence.

* In this region where temperature and potential evaporation change a little throughout the year whereas precipitation changes very large, precipitation plays an important role for crop yield. Under such situations, the above precipitation-based drought indices will give valuable information of the impact of drought on agriculture.

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APPENDIX

Meteorological drought indices used in this study

Deciles Index (DI): The long-term precipitation record is arranged in order from lowest to highest and then spitted into tenths of percentiles, called deciles (Gibbs and Maher, 1967).

Relative Precipitation Index (RPI): Relative precipitation index was determined by the value of the relative precipitation in % (Bąk and Łabędzki, 2002).

Statistical Z-score (Z-score): Sometimes, Z-scores are referred to as "standard scores" (Triola, 1995). The probability of z-score represents the degree of precipitation relative to normal conditions.

China Z Index (CZI): According to Wu et al. (2001), the China Z index is related to Wilson–Hilferty cube-root transformation, as a way to transform $\chi 2$-variables into the standard normal variates (Essenwanger, 1976).

Standardized Precipitation Index (SPI): SPI represents a statistical z-score or the number of standard deviations (following a gamma probability distribution transformed to a normal distribution) above or below that an event is from the mean (Edwards and McKee, 1997). A detailed description and program of SPI calculation can be found at: http://www.drought.unl.edu/monitor/spi/program/spi_program.htm. In this research, the SPI was computed for the 1, 3, 6, 9, 12 and 24 month durations.

The Aridity Index is also used to understand dry and wet variations. It is calculated and used in this study. *Aridity Index (AI):* Aridity index is the ratio between the average precipitation and the average potential evaporation (Hare, 1993). *De Martonne Aridity Index* (I): De Martonne Aridity Index is the ratio between the monthly precipitation amount and monthly mean air temperature (Martonne, 1926).

TABLES

Table 1 Average monthly and yearly precipitation in 1978—2009 (mm)

Table 2 Squared Pearson correlation coefficient values (R^2) of precipitation-based drought indices versus precipitation

Table 3 Squared Pearson correlation coefficient values (R^2) SPI versus other precipitation-based drought indices (CZI,Z-score,RPI,DI,AI)

Table 4 Squared Pearson correlation coefficient values (R^2) of precipitation-based drought indices (CZI, Z-score,RPI,DI,SPI) versus precipitation and potential evaporation-based drought index (AI)

FIGURES

Figure 1 A schematic map of the Southeast Vietnam region showing the location of the 35 selected stations

Figure 2 Monthly average precipitation, potential evaporation and temperature in Tay Ninh station

Figure 3 Seven drought indices and precipitation and potential evaporation on 1-month time scale in 1979 in Tay Ninh station

Figure 4 Six drought indices and precipitation and potential evaporation on 12-month time scale in Bien Hoa station

Figure 5 Scatter diagrams of the SPI and precipitation-based drought indices (CZI, Z-score,RPI,DI) (a),(b),(c) and (d) on 1-month time scale; (e),(f),(g) and (h) on 12-month time scale

Figure 6 Scatter diagrams of precipitation-based drought indices (CZI, Z-score,RPI,DI,SPI) versus precipitation and potential evaporation-based drought index (AI) on 1-month time scale

Figure 7 Scatter diagrams of precipitation-based drought indices (CZI, Z-score,RPI,DI,SPI) versus precipitation and potential evaporation-based drought index (I)

Table 1. Average monthly and yearly precipitation in 1978－2009 (mm)

No.	Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yearly
1	Bien Hoa	6	9	7	76	174	224	269	270	284	236	132	17	1710
2	Long Thanh	7	5	13	51	168	287	285	280	316	285	106	37	1840
3	Xuan Loc	7	9	23	58	158	286	304	378	324	327	102	12	1990
4	Tri An	21	14	23	6	229	300	309	395	338	282	127	31	2080
5	Tuc Trung	18	8	46	106	203	326	302	418	375	310	126	26	2260
6	Tan Phu	16	12	28	126	247	454	415	522	374	362	131	40	2730
7	La Nga	24	10	21	104	226	311	292	470	349	241	88	58	2190
8	Ta Lai	10	14	39	113	245	450	416	510	427	336	138	43	2740
9	Vung Tau	0	0	0	24	154	264	274	194	239	240	60	2	1450
10	Ba Ria	0	0	8	17	148	226	293	192	285	212	12	6	1400
11	Xuyen Moc	0	0	10	32	166	264	272	278	271	195	46	12	1550
12	Dong Phu	9	15	47	142	277	327	328	403	427	352	136	38	2500
13	Phuoc Long	14	16	46	119	301	378	403	468	476	329	133	43	2730
14	Bu Dang	8	15	44	113	254	403	401	500	451	307	119	35	2650
15	Bu Dop	3	8	29	115	305	302	416	436	403	342	66	17	2440
16	Bu Nho	7	8	50	116	236	348	337	374	429	313	126	31	2380
17	Loc Ninh	7	7	38	100	244	274	269	312	405	308	70	33	2070

18	Binh Long	3	8	27	63	133	251	303	423	366	381	128	29	2120
19	Chon Thanh	9	10	38	101	173	259	227	271	379	306	139	43	1960
20	Phuoc Hoa	8	11	25	96	181	265	230	293	324	291	110	38	1870
21	Dau Tieng	8	11	34	102	154	229	255	235	304	274	145	31	1780
22	So Sao	13	5	25	74	169	267	218	260	279	301	132	50	1790
23	Ben Cat	8	4	24	82	149	227	234	226	282	255	134	29	1650
24	Tan Uyen	2	3	22	40	167	224	234	272	258	232	112	23	1590
25	Thuan An	10	6	21	35	138	211	221	216	225	224	121	23	1450
26	Ka Tum	8	3	28	64	183	286	231	282	332	293	88	21	1820
27	Dong Ban	13	12	42	81	151	256	204	221	324	279	124	31	1740
28	Can Dang	14	8	26	97	188	246	225	243	283	278	115	28	1750
29	Tay Ninh	14	9	24	108	210	265	265	232	327	310	127	42	1930
30	Ben Soi	15	4	27	105	149	195	172	171	279	317	127	59	1620
31	Go Dau Ha	11	3	27	84	184	244	214	206	289	270	139	40	1710
32	Cu Chi	1	1	2	35	210	285	290	276	290	263	140	28	1820
33	Tan Son Hoa	13	14	10	58	213	294	290	283	294	265	120	48	1900
34	Nha Ba	1	1	2	28	154	277	253	269	280	184	68	20	1540
35	Can Gio	1	1	5	9	97	212	206	143	185	189	47	2	1100
/	Average	9	8	25	77	193	283	282	312	328	283	110	30	1939

Table 2. Squared Pearson correlation coefficient values (R^2)

of precipitation-based drought indices versus precipitation

Time scale (months)	1	3	6	9	12	24
RPI vs Precipitation	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Z-score vs Precipitation	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
CZI vs Precipitation	1.0000	1.0000	1.0000	1.0000	1.0000	0.9986
DI vs Precipitation	0.9741	0.9856	0.9904	0.9864	0.9934	0.9905
SPI vs Precipitation	0.1638	0.1691	0.2714	0.4022	0.9831	0.9965

Table 3. Squared Pearson correlation coefficient values (R^2) SPI versus other precipitation-based drought indices (CZI,Z-score,RPI,DI,AI)

Time scale (months)	1	3	6	9	12	24
SPI vs CZI	0.1641	0.1698	0.2714	0.4022	0.9938	0.9995
SPI vs Z-score	0.1638	0.1691	0.2714	0.4022	0.9934	0.9965
SPI vs RPI	0.1638	0.1691	0.2714	0.4022	0.9934	0.9965
SPI vs DI	0.1585	0.1625	0.2509	0.4090	0.9778	0.9867
SPI vs AI	0.1534	0.1616	0.2081	0.3536	0.7222	0.6857

Table 4. Squared Pearson correlation coefficient values (R^2) of precipitation-based drought indices (CZI,Z-score,RPI,DI,SPI) versus precipitation and potential evaporation-based drought index (AI)

Time scale (months)	1	3	6	9	12	24
CZI vs AI	0.9060	0.9029	0.7811	0.8730	0.7344	0.6932
Z-score vs AI	0.9059	0.9021	0.7811	0.8730	0.7347	0.7063
RPI vs AI	0.9059	0.9021	0.7811	0.8730	0.7347	0.7063
DI vs AI	0.8938	0.8913	0.7609	0.8672	0.7359	0.6797
SPI vs AI	0.1534	0.1616	0.2081	0.3536	0.7222	0.6857

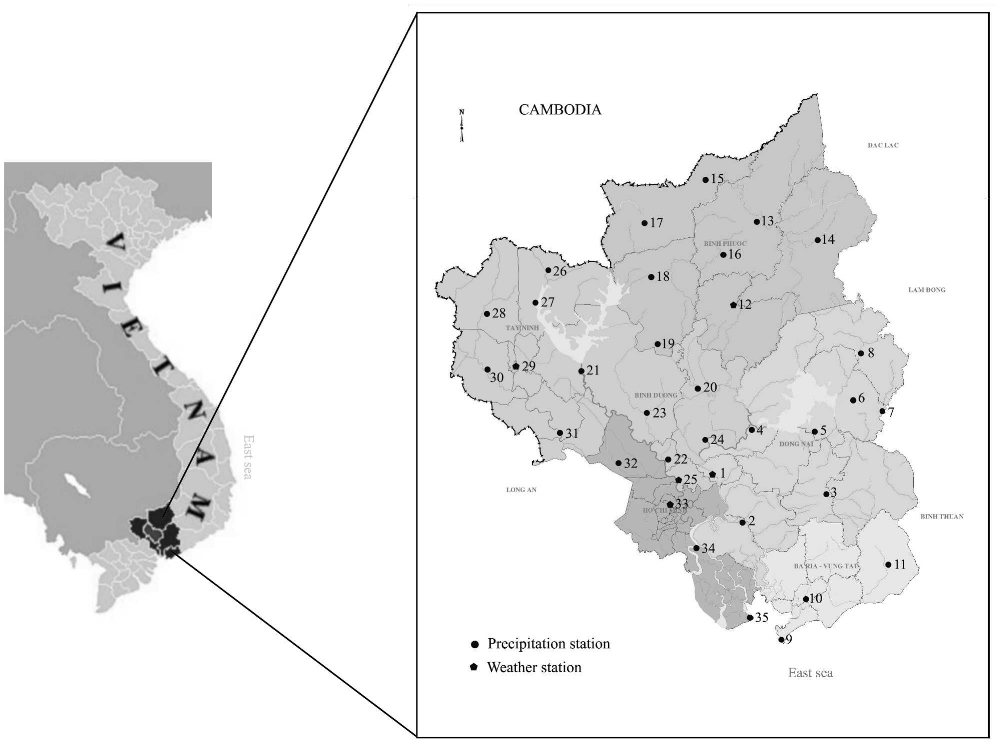

Figure 1. A schematic map of the Southeast Vietnam region showing the location of the 35 selected stations
203x151mm (500 x 500 DPI)

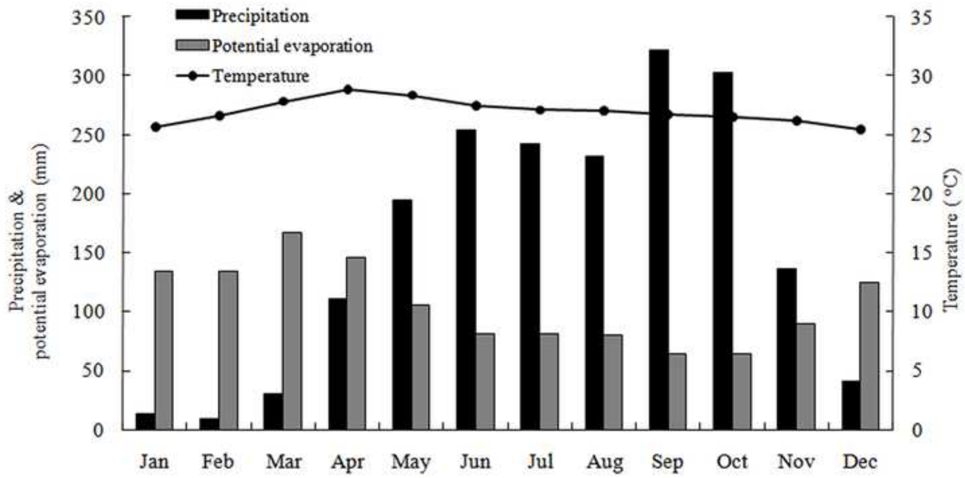

Figure 2. Monthly average precipitation, potential evaporation and temperature in Tay Ninh station
31x15mm (600 x 600 DPI)

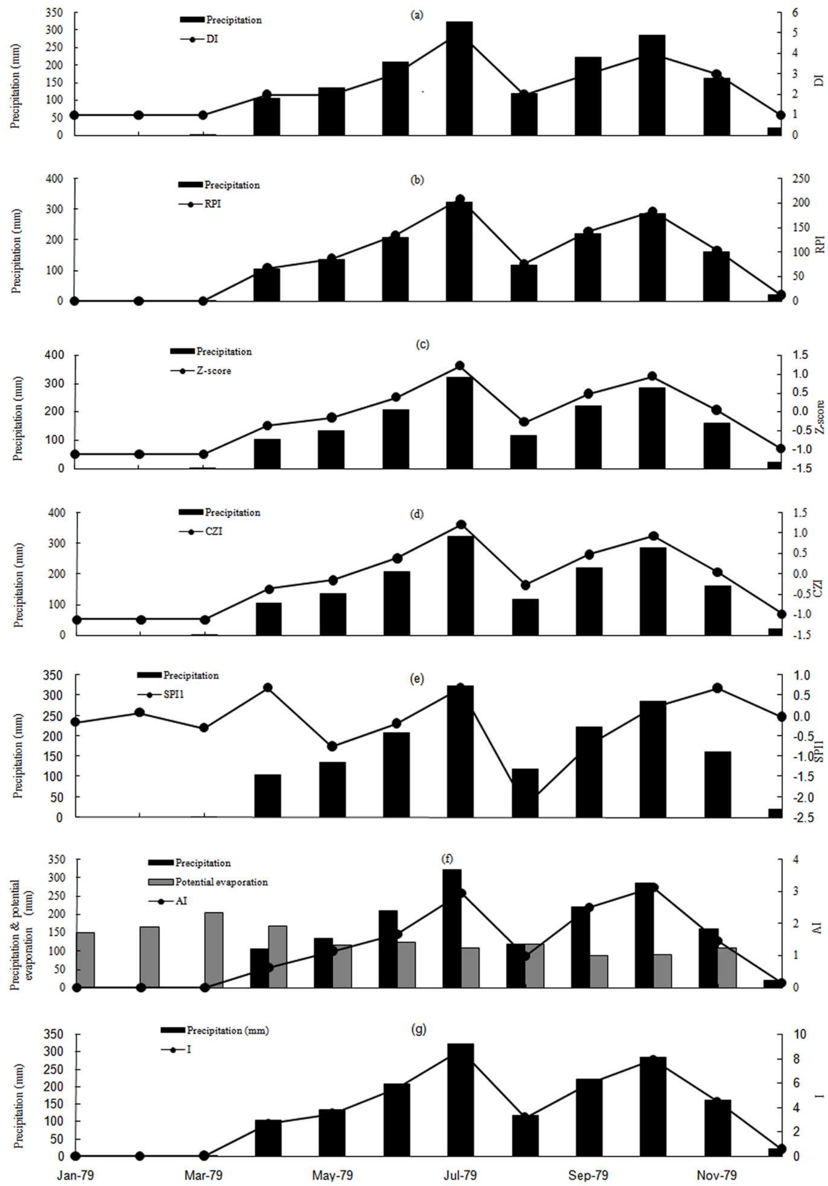

Figure 3. Seven drought indices and precipitation and potential evaporation on 1-month time scale in 1979 in Tay Ninh station
179x253mm (600 x 600 DPI)

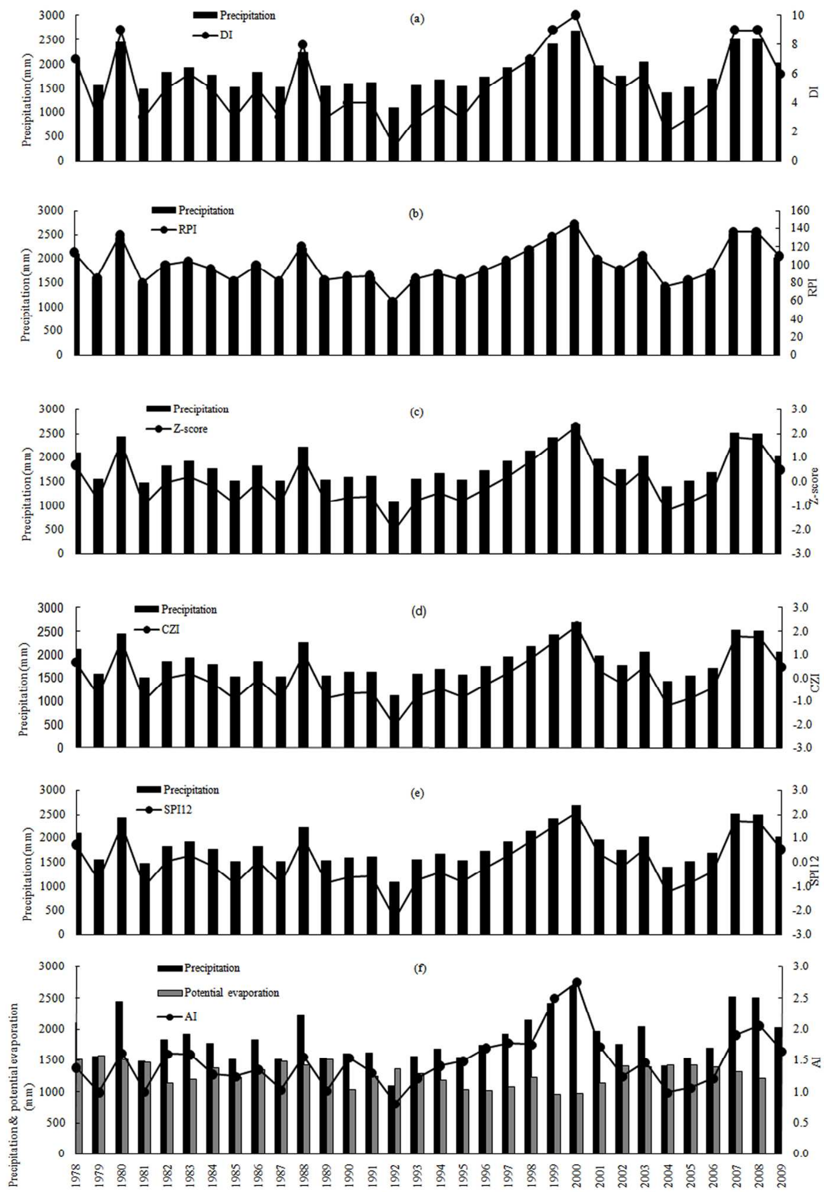

Figure 4. Six drought indices and precipitation and potential evaporation on 12-month time scale in Bien Hoa station
182x259mm (600 x 600 DPI)

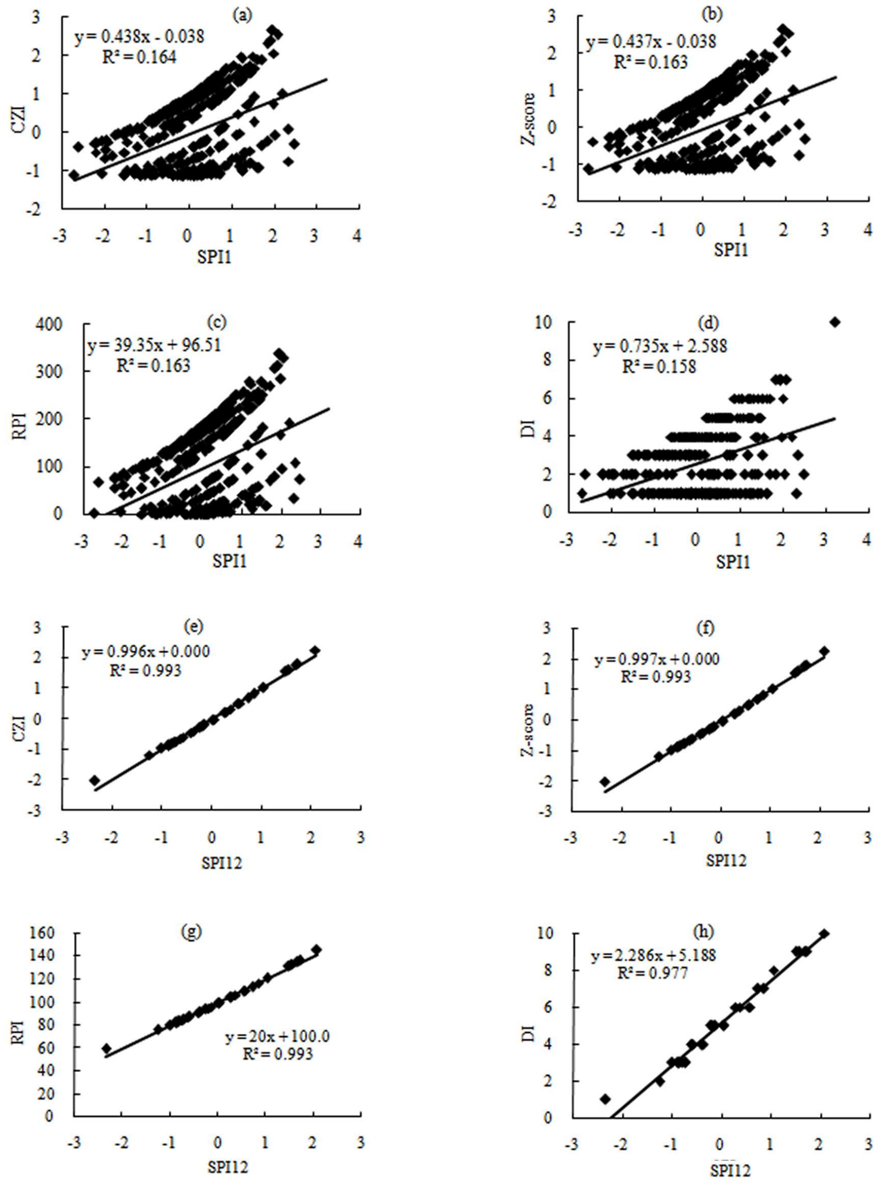

Figure 5. Scatter diagrams of the SPI and precipitation-based drought indices (CZI,Z-score,RPI,DI) (a),(b),(c) and (d) on 1-month time scale; (e),(f),(g) and (h) on 12-month time scale
149x200mm (600 x 600 DPI)

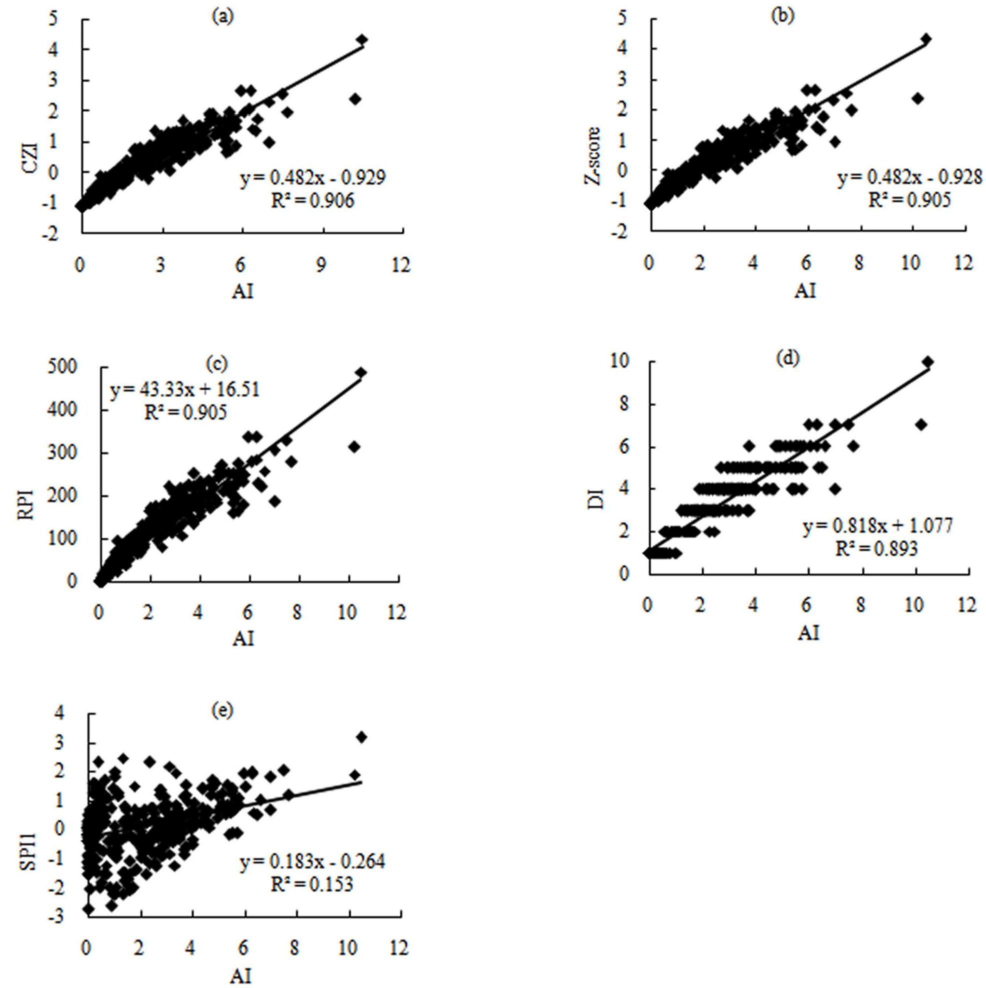

Figure 6. Scatter diagrams of precipitation-based drought indices (CZI,Z-score,RPI,DI,SPI) versus precipitation and potential evaporation-based drought index (AI) on 1-month time scale
114x117mm (600 x 600 DPI)

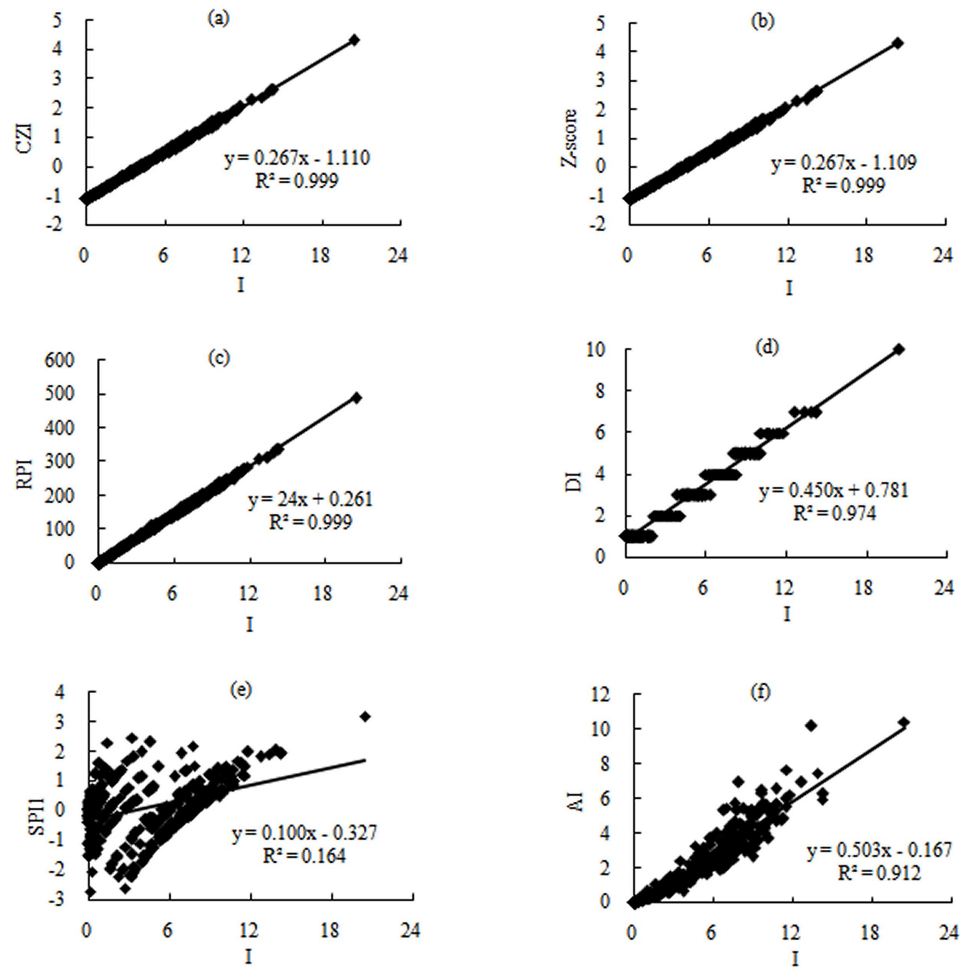

Figure 7. Scatter diagrams of precipitation-based drought indices (CZI,Z-score,RPI,DI,SPI) versus precipitation and potential evaporation-based drought index (I)
111x111mm (600 x 600 DPI)