Analysis of total monthly precipitation of Susurluk Basin in Turkey using innovative polygon trend analysis method

Gokmen Ceribasi and Ahmet Iyad Ceyhunlu

ABSTRACT

The effects of climate change caused by global warming can be seen in changes of climate variables such as precipitation, humidity, and temperatures. These effects of global climate change can be interpreted as a result of the examination of meteorological parameters. One of the most effective methods to investigate these effects is trend analysis. The Innovative Polygon Trend Analysis (IPTA) method is a trend analysis method that has emerged in recent years. The distinctive features of this method compared with other trend methods are that it depends on time series and can compare data series among themselves. Therefore, in this study, the IPTA method was applied to total monthly precipitation data of Susurluk Basin, one of Turkey's important basins. Data from ten precipitation observation stations in Susurluk Basin were used. Data were provided by the General Directorate of State Meteorology Affairs. The length of this data series was 12 years (2006–2017). As a result of the study, since there is no regular polygon in IPTA graphics of each station, it is seen that precipitation data varies by years. While this change is seen increasingly at some stations, it is seen decreasingly at other stations.

Key words | Innovative Polygon Trend Analysis (IPTA), precipitation, Susurluk Basin, Turkey

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HIGHLIGHTS

- Application Innovative Polygon Trend Analysis Method is for Susurluk Basin in Turkey.
- Polygon trend analysis statistical values are derived.
- Trend Length and Trend Slope components are identified.
- The impact of climate change was investigated using innovative Polygon Trend Analysis Method.

INTRODUCTION

While climate is defined as the average of long-term weather events of a region, global climate change is defined as changes occurring in climate elements. The effects of climate change caused by global warming are seen on parameters such as precipitation, humidity, air movements, sea surface temperatures, and air temperatures. These effects of global climate change can be interpreted as a result of the examination of physical parameters (such as meteorological, oceanographic, or geophysical parameters) (Mohorji *et al.* 2017; Wu & Qian 2017; Ceribasi 2018).

Climate change resulting from global warming shows its effect in almost every region of the world. The impact of this climate change occurs as water scarcity in some regions, and it occurs as floods in some regions. People experience great difficulties from both effects. Therefore, studies on the issue of climate change have been increasing recently. In particular, it is seen that studies performed as forward-prediction models are increasing. However, data used in these studies

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do not establish an approach in transition between days, weeks, months, and years. In this context, the Innovative Polygon Trend Analysis (IPTA) method establishes an approach in transition between days, weeks, months, and years. Hence, it is seen that the IPTA method will be used frequently in academic studies (Sen *et al.* 2019).

The mean and standard deviation changes in hydro-meteorological variables are very important in different human activities such as water supply, hydroelectric power generation, agricultural activities, and irrigation practices. In literature, there are various methodologies for assessment of time series trend component and variability changes. The most common of these methodologies are trend analysis tests such as the Mann–Kendall test, Mann–Kendall Rank Correlation test, Trend Slope test, and Innovative Trend Analysis (Mann 1945; Sen 1968, 2012; Kendall 1975). These methods have been applied frequently by many researchers (Bocheva *et al.* 2009; Wilson *et al.* 2010; Reihan *et al.* 2012; Jones *et al.* 2015; Zhang *et al.* 2015; Ceribasi & Dogan 2016; Dabanli *et al.* 2016; Tabari *et al.* 2017; Almazroui *et al.* 2018; Ceribasi 2018, 2019; Dabanli & Sen 2018; Han & Singh 2020; Li *et al.* 2020; Nikakhtar *et al.* 2020). In addition, Alexander *et al.* (2006) calculated and analyzed a series of climate change indices derived from daily temperature and

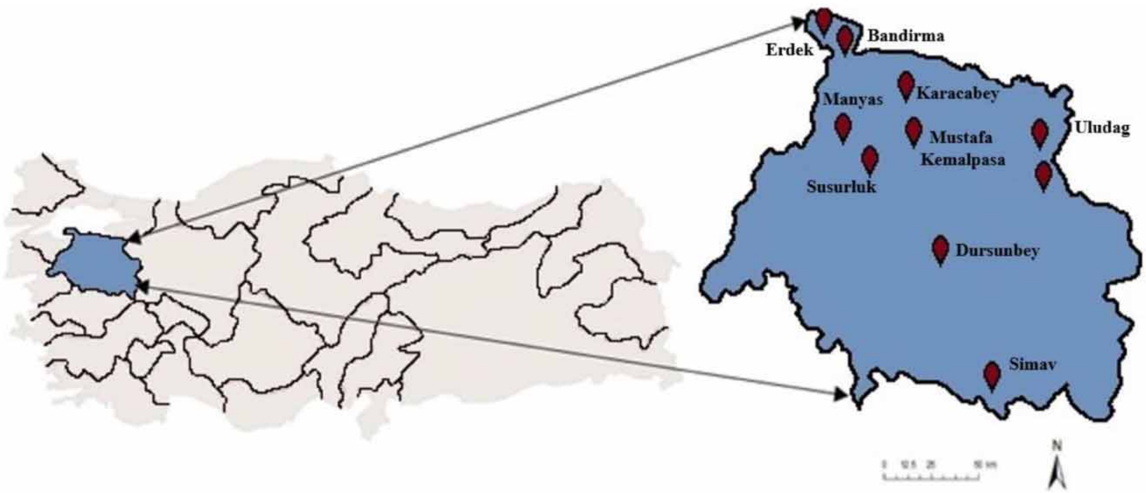

Figure 1 | Location of Susurluk Basin and stations on map of Turkey's basins.

Table 1 | Information of observation stations

No.	Station name	Station No.	Location		Altitude (m)
			Latitude	Longitude	
1	Bandirma	17,114	40°19′53.4″N	27°59′47.4″E	20.00
2	Erdek	17,635	40°23′.9″N	27°47′.6″E	180.00
3	Karacabey	17,673	40°07′.8″N	28°19′.2″E	15.00
4	Uludag	17,676	40°06′27.0″N	29°07′.4″E	2,543.00
5	Keles	17,695	39°54′54.0″N	29°13′.7″E	1,240.00
6	Manyas	17,699	40°02′49.6″N	27°58′.3″E	50.00
7	Dursunbey	17,700	39°34′40.1″N	28°37′.9″E	672.00
8	Susurluk	17,705	39°55′02.3″N	28°09′52.9″E	63.00
9	Simav	17,748	39°05′33.0″N	28°58′.0″E	830.00
10	Mustafa Kemalpasa	17,675	40°02′.0″N	28°23′58.2″E	60.00

precipitation data, focusing on extreme events. As a result, differences in temperature index distributions showed that they would be particularly prominent between the last two periods and for indices related to minimum temperature and that there would be a tendency towards more rainy conditions throughout the 20th century (Alexander *et al.* 2006). Niu *et al.* (2019) analyzed air temperature from 1961 to 2014 in the Yellow and Yangtze river basins and made a

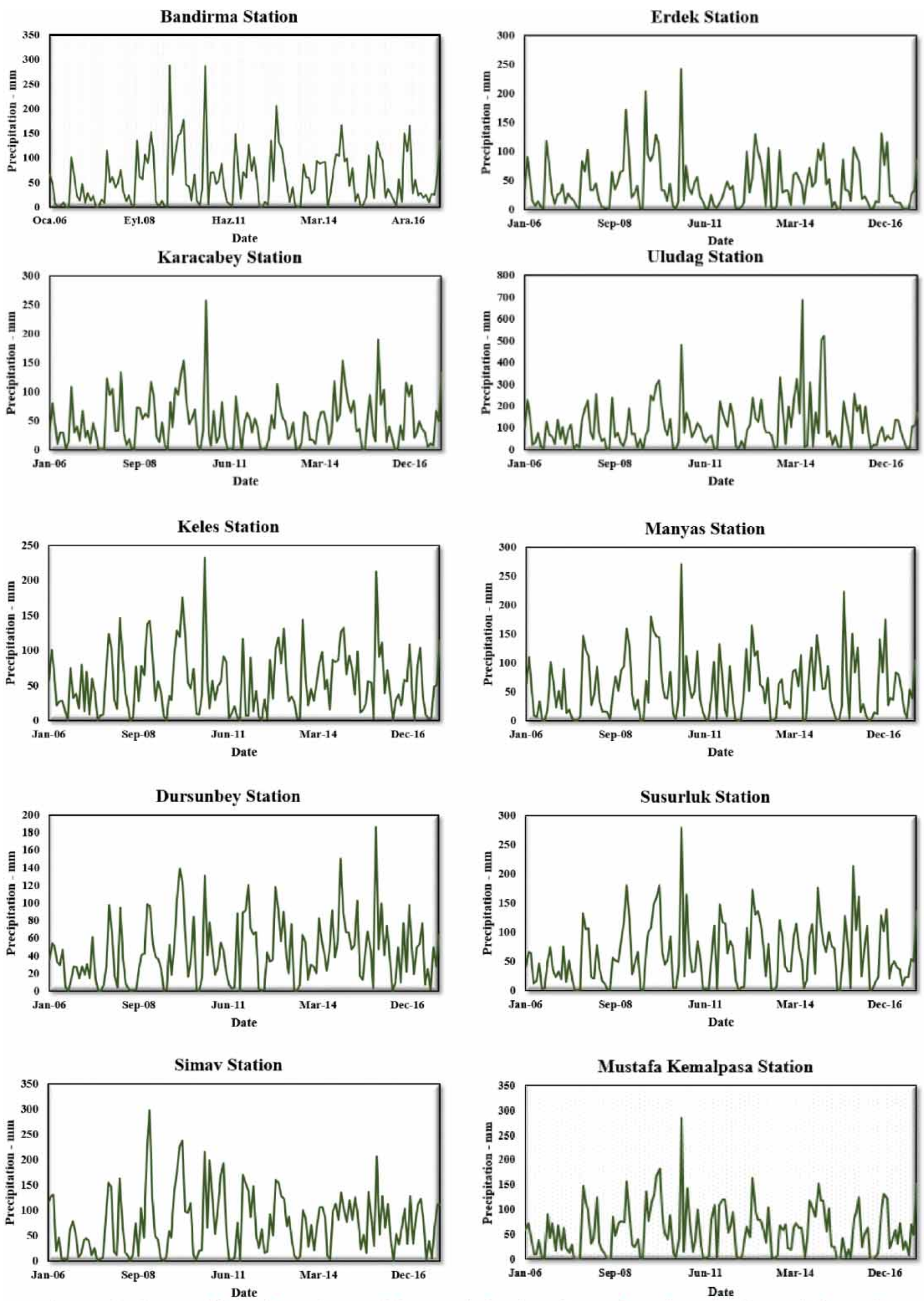

Figure 2 | Course line of total monthly precipitation data of stations in Susurluk Basin.

comparison using 16 temperature indices provided by ETCCDI and using a series of high-density observations from 300 weather stations. Sen *et al.* (2019) proposed the IPTA method in their study. They analyzed the three hydro-meteorological data sets from different parts (rainfall and stream New Jersey (USA), Danube River (Romania) and Goksu River (Turkey)) of the world. While these trend analysis tests are applied, there may be a linear relationship and a nonlinear (stochastic) relationship between hydro-meteorological data and time.

The purpose of trend analysis tests is to make future predictions about objective, quantitative, and systematic detection, identification, and prediction mechanisms of linear or nonlinear data over time. For this reason, trend analysis is widely applied in many fields, especially in the field of engineering. Furthermore, it is observed that it is widely used in climate change research arising from global warming (Sen *et al.* 2019).

The IPTA method is a new trend test and it is the newest trend analysis method in recent years. The purpose of this method is to establish a relationship between available data. Other trend methods show weakness in this area since they do not establish an approach in seasonal transitions. Since the IPTA method establishes an approach in seasonal transitions, it will be preferable to other trend tests. Therefore, in this study, the IPTA method will be applied to total monthly precipitation data of Susurluk Basin, one of Turkey's important basins. The reason for choosing Susurluk Basin in this study is that it is a basin with high population density and industry. Therefore, it is important to analyze this region in terms of climate change. Data from ten precipitation observation stations in Susurluk Basin are used. Data are provided by the General Directorate of State Meteorology Affairs. The length of this data series is 12 years (2006–2017).

MATERIALS AND METHODS

Study area

Susurluk Basin is one of Turkey's most important basins. The basin has a total precipitation area of 24,332 km^2. Important streams of the basin are Nilufer Stream, Mustafakemalpasa Stream, Simav Stream, and Koca Stream. Annual water potential is $6.08 \times 10^9\ m^3$. Uluabat and Manyas Lakes are located in this basin. Susurluk Basin is located in the south of the Marmara region and includes some of Bursa, Balıkesir, Kutahya, Bilecik, Canakkale, Manisa, and Izmir provinces (Dorum *et al.* 2010; Bulut & Saler 2018; Albayrak *et al.* 2019). The location of Susurluk Basin and stations selected for this study are shown in Figure 1.

Total monthly precipitation data for the region used in this study was taken from the General Directorate of State Meteorology Affairs (DMI). Information from stations used in the study is given in Table 1.

The course line of total monthly precipitation data of the observation stations (Bandirma, Erdek, Karacabey, Uludag, Keles, Manyas, Dursunbey, Susurluk, Simav, and Mustafa Kemalpasa) in Susurluk Basin are given in Figure 2. The length of this data series is 12 years (2006–2017).

IPTA method

The IPTA method was obtained by the development of the Innovation Trend Analysis method, which was introduced by Sen in the years 2012, 2014, and 2017 (Sen 2012, 2014, 2017a, 2017b; Sen *et al.* 2019). In this method, time scales of

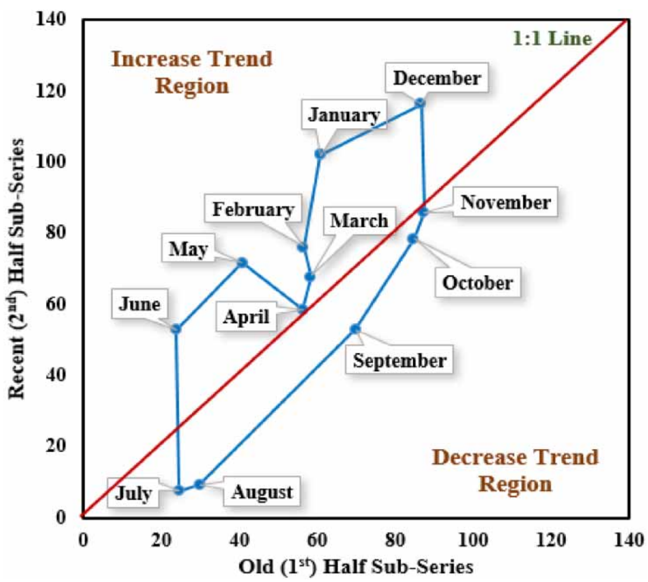

Figure 3 | Hypothetical Innovative Polygon Trend Analysis template for monthly records.

data can be daily, monthly, or yearly. If the IPTA method is applied to monthly data written in a matrix format, row data will consist of monthly data in a year. Monthly meteorological data are $X_{1,n}$, $X_{2,n}$, ……, $X_{i,n}$ (i represents the number of months and n represents the number of years). The written matrix is divided into two equal series

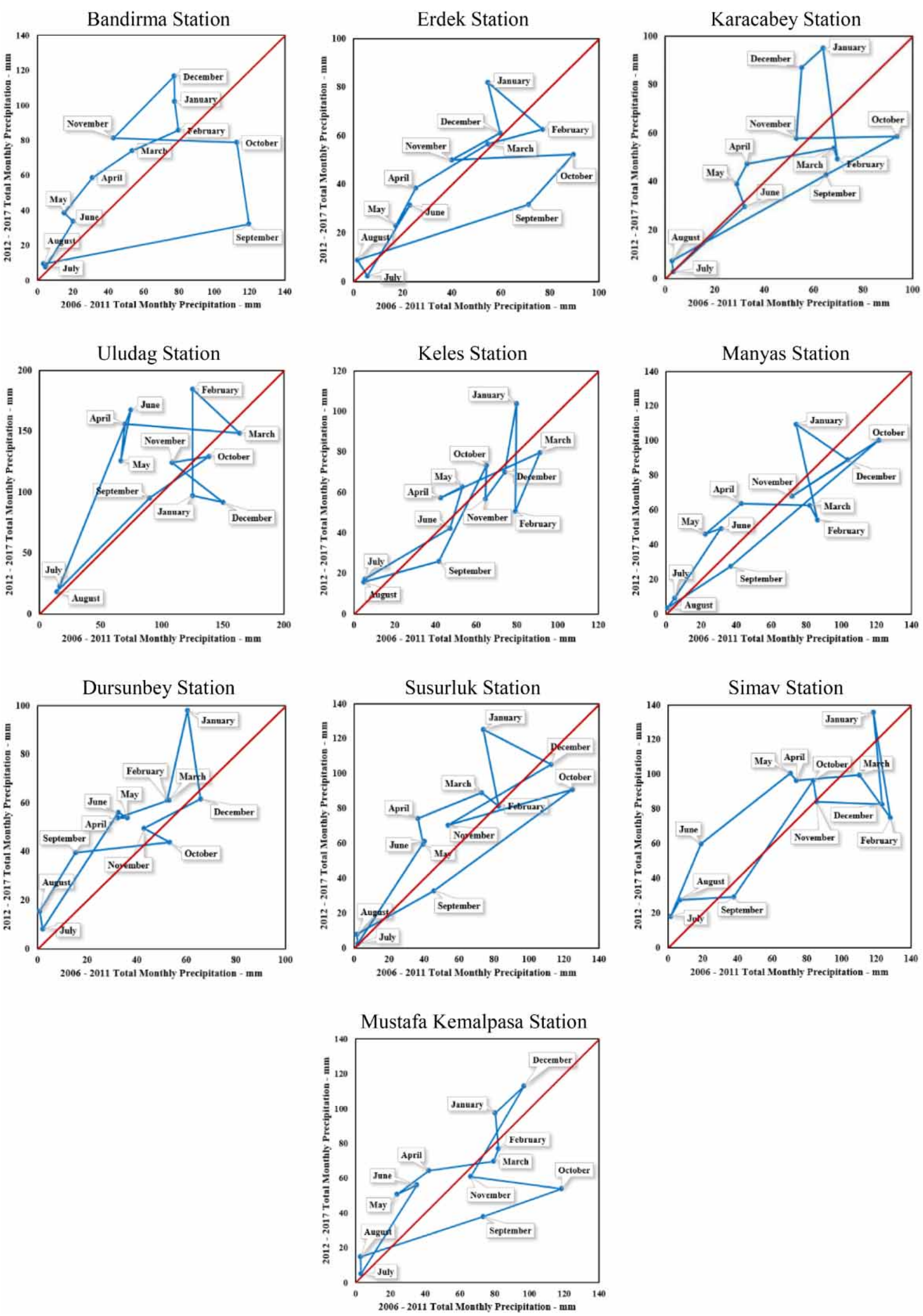

Figure 4 | Innovative Polygon Trend Analysis Method graphics of arithmetic mean analysis results for each station.

at top and bottom and converted to the matrix format as follows. Data series are divided into two equal parts and the mean and standard deviation of each series are calculated. In the Cartesian system, means of upper series are placed on the X-axis and means of lower series are placed on the Y-axis. A trend polygon end point for each month is created as in Figure 3.

$$\begin{bmatrix} x_{1,1}, & x_{1,2}, & \cdots & , x_{1,12} \\ x_{2,1}, & x_{2,2}, & \cdots & , x_{2,12} \\ \cdots & \cdots & \cdots & \cdots \\ x_{i,1}, & x_{i,2}, & \cdots & , x_{i,12} \\ \cdots & \cdots & \cdots & \cdots \\ x_{n,1}, & x_{n,2}, & \cdots & , x_{n,12} \end{bmatrix} \begin{matrix} \text{Upper Series (First Half) n=1,2,3,.....,n/2} \\ \\ \text{Lower Series (Second Half) n=n/2+1, n/2+2,.....,n} \end{matrix}$$

As seen in Figure 3, the polygonal end points of each month are combined with each other. Each line connecting all points creates trend information. The distribution of points in the figure varies depending on the effects of hydro-meteorological events. Figure 3 shows decreasing lines after rising lines on the polygon. These changes in lines show how change occurred in hydro-meteorological data between months. For example, Figure 3 shows an increasing trend in January, February, March, April, May, June, and December while a decreasing trend is seen in July, August, September, October, and November. Considering that this data set belongs to precipitation data, it is concluded that there will be an increase in precipitation in January, February, May, and June. In this way, the polygon cycle is completed. If data have a homogeneous structure, the result of analysis will consist of a single polygon. However, depending on the complexity of the data analyzed, more complex and multiple polygons may occur in the analysis.

RESULTS AND DISCUSSION

The IPTA method was applied to total monthly precipitation data of Susurluk Basin, one of Turkey's important basins. Data of ten precipitation observation stations (Bandirma, Erdek, Karacabey, Uludag, Keles, Manyas, Dursunbey, Susurluk, Simav, and Mustafa Kemalpasa) in Susurluk Basin were used. IPTA method graphics of arithmetic mean analysis results for each station are given in Figure 4.

General evaluation of arithmetic mean analysis results for each station in Figure 4 are given in Table 2.

When analysis results of Table 2 are examined, the fact that polygons in each station are irregular and complex arises because the arithmetic mean is not constant and data do not change systematically. Precipitation data in each station are not homogeneous and isotropic. No single polygon was created at any station. This shows that precipitation data have instability. When results given in Table 2 are analyzed for each station, upward arrows in months show that there is more precipitation than the first series (2006–2011), and downward arrows in months show that there is more precipitation than the second series (2012–2017). In addition, horizontal directional arrows in months show that there is the same amount of precipitation on average in both series. For example, for Bandirma Station, it is seen in ten months (January, February, March, April, May, June, July, August, November, and December) that there is more precipitation than the first series (2006–2011) and for two months (September and October) there is more precipitation than the second series (2012–2017).

IPTA method graphics of standard deviation analysis results for each station are given in Figure 5.

General evaluation of standard deviation results for each station in Figure 5 are given in Table 3.

When the analysis results of Table 3 are examined, the fact that polygons in each station are irregular and complex arises because the arithmetic mean is not constant and data

Table 2 | General evaluation of arithmetic mean analysis results for each station

Stations	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Bandirma	↗	↗	↗	↗	↗	↗	↗	↗	↘	↘	↗	↗
Erdek	↗	↘	↗	↗	↗	↗	↘	↗	↘	↘	↗	↗
Karacabey	↗	↘	↘	↗	↗	↘	→	↗	↘	↘	↗	↗
Uludag	↘	↗	↘	↗	↗	↗	↗	↗	↗	↘	↗	↘
Keles	↗	↘	↘	↗	↗	↗	↗	↗	↘	↗	↘	↘
Manyas	↗	↘	↘	↗	↗	↗	↗	↗	↘	↘	↘	↘
Dursunbey	↗	↗	↗	↗	↗	↗	↗	↗	↗	↘	↗	↘
Susurluk	↗	→	↗	↗	↗	↗	→	↗	↘	↘	↗	↘
Simav	↗	↘	↘	↗	↗	↗	↗	↗	↘	↗	→	↘
Mustafa Kemalpasa	↗	↘	↘	↗	↗	↗	→	↗	↘	↘	↘	↗

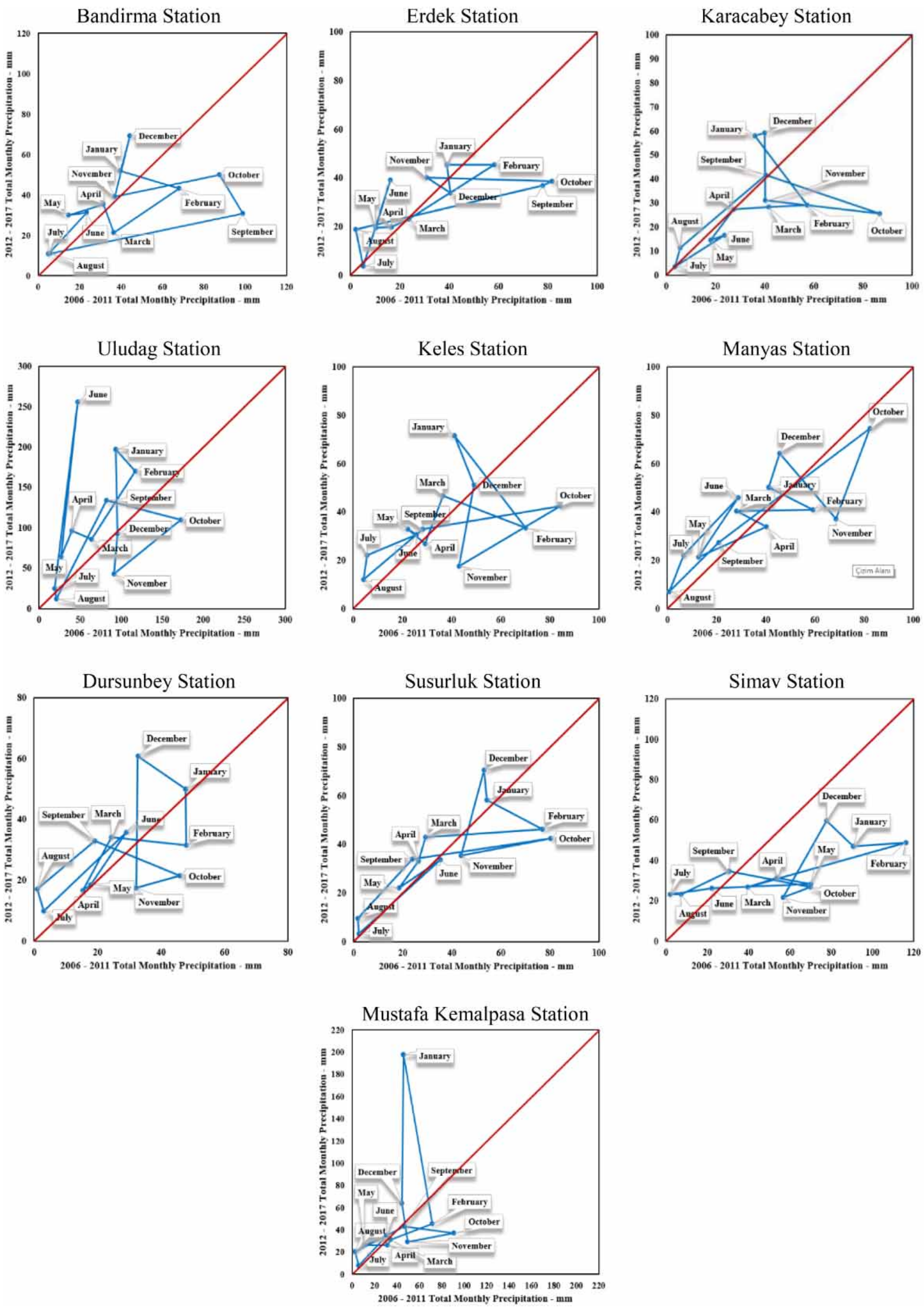

Figure 5 | Innovative Polygon Trend Analysis Method graphics of standard deviation analysis results for each station.

do not change systematically. Precipitation data in each station is not homogeneous and isotropic. No single polygon was created at any station. This shows that precipitation data have instability. When results given in Table 3 are analyzed for each station, upward arrows in months show that there is more precipitation than the first series (2006–2011), and downward arrows in months show that there is more precipitation than the second series (2012–2017). In addition, horizontal directional arrows in months show that there is the same amount of precipitation on average in both series. For example, for Bandirma Station, it is seen in eight months (January, April, May, June, July, August, November, and December) that there is more precipitation than the first series (2006–2011) and in four months (February, March, September, and October) there is more precipitation than the second series (2012–2017).

Statistical values of arithmetic mean and standard deviation of five stations (Bandirma, Erdek, Karacabey, Uludag, and Keles) are given in Table 4 and statistical values of arithmetic mean and standard deviation of the other five stations (Manyas, Dursunbey, Susurluk, Simav, and Mustafa Kemalpasa) are given in Table 5.

The results given in Table 4 indicate transition between months. The maximum values are interpreted to mean transition between two months will violently occur. When statistical values of arithmetic mean and standard deviation for five stations (Bandirma, Erdek, Karacabey, Uludag, and Keles) are examined, for Bandirma Station, max. trend length is, respectively, 118.42 mm and 95.05 mm, and max. trend slope is calculated as −432 and 4.06. For Erdek Station, max. trend length is, respectively, 73.21 mm and 77.85 mm, and max. trend slope is calculated as −3.97 and −8.81. For Karacabey Station, max. trend length is, respectively, 71.69 mm and 46.81 mm, and max. trend slope is calculated as 13.86 and −113.56. For Uludag Station, max. trend length is, respectively, 880.84 mm and 1,882.01 mm, and max. trend slope is calculated as −5,906.75 and −837.34. For Keles Station, max. trend length is, respectively, 53.67 mm and 56.87 mm, and max. trend slope is calculated as 114.07 and 7.26.

Table 3 | General evaluation of standard deviation analysis results for each station

Stations	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Bandirma	↗	↘	↘	↗	↗	↗	↗	↗	↘	↘	↗	↗
Erdek	↗	↘	→	↗	↗	↗	→	↗	↘	↘	↗	↘
Karacabey	↗	↘	↘	→	↘	↘	→	↗	→	↘	↘	↗
Uludag	↗	↗	↗	↗	↗	↗	→	↘	↗	↘	↘	→
Keles	↗	↘	↗	↘	↗	↗	↗	↗	↗	↘	↘	↗
Manyas	↗	↘	↗	↘	↗	↗	↗	↗	↗	↘	↘	↗
Dursunbey	↗	↘	↗	↗	→	↗	↗	↗	↗	↘	↘	↗
Susurluk	↗	↘	↗	↗	↗	→	→	↗	↗	↘	↘	↗
Simav	↘	↘	↘	↘	↘	↗	↗	↗	↗	↘	↘	↘
Mustafa Kemalpasa	↗	↘	→	↘	↗	↗	→	↗	→	↘	↘	↗

The results given in Table 5 indicate transition between months. The maximum values are interpreted as transition between two months will violently occur. When statistical values of arithmetic mean and standard deviation for five station (Manyas, Dursunbey, Susurluk, Simav, and Mustafa Kemalpasa) are examined: For Manyas Station, max. trend length is, respectively, 111.50 mm and 77.48 mm, and max. trend slope is calculated as −4.55 and 3.03. For Dursunbey Station, max. trend length is, respectively, 38.19 mm and 43.43 mm, and max. trend slope is calculated as −6.72 and 89.46. For Susurluk Station, max. trend length is, respectively, 98.09 mm and 57.09 mm, and max. trend slope is calculated as −7.85 and −22.64. For Simav Station, max. trend length is, respectively, 81.28 mm and 79.56 mm, and max. trend slope is calculated as −10.47 and 1.80. For Mustafa Kemalpasa Station, max. trend length is, respectively, 74.21 mm and 49.58 mm, and max. trend slope is calculated as −32.22 and −18.53.

The results of the analysis gave similar results to studies for this study area (Aytulun 2019; Ceribasi & Aytulun 2020). Hence, the method used in this study can be used in similar studies (climate model, river flow model, etc.).

CONCLUSION

In this study, the IPTA method was applied to total monthly precipitation data of Susurluk Basin. Ten stations (Bandirma, Erdek, Karacabey, Uludag, Keles, Manyas, Dursunbey, Susurluk, Simav, and Mustafa Kemalpasa) were selected in Susurluk Basin. The length of precipitation data used in the study is 12 years (2006–2017). As a result of the study, IPTA graphics were created for each station. In addition, trend lengths and trend slopes of monthly total

Table 4 | Statistical values of arithmetic mean and standard deviation of five stations (Bandirma, Erdek, Karacabey, Uludag and Keles)

Station		Jan–Feb	Feb–Mar	Mar–Apr	Apr–May	May–Jun	Jun–Jul	Jul–Aug	Aug–Sep	Sep–Oct	Oct–Nov	Nov–Dec	Dec–Jan
Bandirma													
Arithmetic mean	Trend length (mm)	16.76	28.69	27.28	25.58	6.88	30.38	2.10	**118.42**	47.12	69.51	49.27	14.40
	Trend slope	− 7.22	0.44	0.69	1.27	− 0.96	1.69	− 1.43	0.20	− 6.59	− 0.04	1.03	− **432.00**
Standard deviation	Trend length (mm)	29.78	38.41	15.01	17.72	8.95	27.63	0.92	**95.05**	22.19	51.76	30.99	18.05
	Trend slope	− 0.30	0.69	− 2.76	0.31	0.14	1.12	0.40	0.21	− 1.69	0.22	**4.06**	3.69
Erdek													
Arithmetic mean	Trend length (mm)	29.55	23.11	34.51	17.48	10.18	33.80	7.54	**73.21**	27.66	49.69	22.81	21.31
	Trend slope	− 0.85	0.27	0.62	1.86	1.48	1.68	− 1.64	0.33	1.12	0.05	0.56	− **3.97**
Standard deviation	Trend length (mm)	19.31	41.42	7.71	6.35	20.37	37.18	15.47	**77.85**	4.09	50.90	11.53	11.71
	Trend slope	0.002	0.64	0.47	0.01	3.34	3.27	− 5.11	0.24	0.43	− 0.03	− 0.67	− **8.81**
Karacabey													
Arithmetic mean	Trend length (mm)	46.10	4.77	35.70	9.30	9.89	39.43	4.56	**71.69**	32.77	40.77	29.18	11.74
	Trend slope	− 7.71	− 2.95	0.18	1.98	− 2.96	0.93	− 9.07	0.57	0.55	0.01	**13.86**	0.91
Standard deviation	Trend length (mm)	35.94	15.68	14.32	15.94	5.83	23.79	7.97	46.33	49.03	**46.81**	28.11	4.05
	Trend slope	− 1.36	0.05	0.06	1.37	0.34	0.64	3.81	0.87	− 0.35	− 0.12	− **113.56**	0.29
Uludag													
Arithmetic mean	Trend length (mm)	787.57	52.78	94.47	30.70	42.96	156.36	5.10	108.18	59.31	30.46	53.18	**880.84**
	Trend slope	− **5,906.75**	− 0.94	− 0.08	9.44	5.02	2.50	1.78	1.02	0.70	0.16	− 0.79	− 35.27
Standard deviation	Trend length (mm)	1,805.13	99.47	26.19	34.81	192.79	233.08	12.91	136.54	93.85	105.49	50.52	**1.882.01**
	Trend slope	− 75.60	1.56	− 0.43	2.46	9.39	8.27	− 5.83	2.01	− 0.27	0.83	11.35	− **837.34**
Keles													
Arithmetic mean	Trend length (mm)	53.24	31.53	**53.67**	12.10	21.48	48.61	1.62	38.22	52.88	16.47	16.22	34.22
	Trend slope	**114.07**	2.44	0.46	0.52	3.32	0.60	2.88	0.28	2.03	32.93	1.40	5.85
Standard deviation	Trend length (mm)	47.96	36.40	21.16	9.23	4.15	21.87	10.19	31.82	**56.87**	48.22	34.37	21.68
	Trend slope	− 1.32	− 0.40	2.80	− 0.85	− 0.65	0.41	**7.26**	0.86	0.17	0.60	5.52	− 2.56

Table 5 | Statistical values of arithmetic mean and standard deviation of five stations (Manyas, Dursunbey, Susurluk, Simav and Mustafa Kemalpasa)

Stations		Jan–Feb	Feb–Mar	Mar–Apr	Apr–May	May–Jun	Jun–Jul	Jul–Aug	Aug–Sep	Sep–Oct	Oct–Nov	Nov–Dec	Dec–Jan
Manyas													
Arithmetic mean	Trend length (mm)	56.83	9.53	39.29	27.01	9.42	47.80	7.09	43.36	**111.50**	59.22	37.91	35.76
	Trend slope	− **4.55**	− 1.96	− 0.03	0.86	0.33	1.51	1.40	0.66	0.86	0.65	0.67	− 0.71
Standard deviation	Trend length (mm)	20.44	31.05	13.86	30.49	29.50	32.64	16.12	28.61	**77.48**	39.86	35.58	14.80
	Trend slope	− 0.52	0.01	− 0.54	0.45	1.51	1.07	2.61	1.01	0.77	2.69	− 1.19	**3.03**
Dursunbey													
Arithmetic mean	Trend length (mm)	37.76	0.80	22.03	3.90	4.24	56.76	7.49	28.10	**38.19**	11.69	25.90	36.67
	Trend slope	4.51	− 0.10	0.35	0.01	− 0.62	1.57	− 5.53	1.66	0.11	− 0.57	0.54	− **6.72**
Standard deviation	Trend length (mm)	18.63	23.76	19.65	3.14	20.44	36.56	7.39	24.19	29.15	14.34	**43.43**	18.53
	Trend slope	− 81.23	− 0.11	1.92	0.71	1.54	1.00	− 3.29	0.87	− 0.43	0.29	**89.46**	− 0.71
Susurluk													
Arithmetic mean	Trend length (mm)	44.69	12.43	39.27	15.32	1.89	69.88	5.28	50.73	**98.09**	74.08	68.49	43.40
	Trend slope	− 4.94	− 0.79	0.40	− 4.84	3.93	1.55	− **7.85**	0.57	0.73	0.29	0.59	− 0.51
Standard deviation	Trend length (mm)	25.66	47.91	10.22	13.69	20.44	45.02	6.23	33.02	**57.09**	37.28	36.51	12.40
	Trend slope	− 0.53	0.07	3.65	1.38	0.69	0.91	− **22.64**	1.11	0.15	0.20	3.71	− 11.50
Simav													
Arithmetic mean	Trend length (mm)	61.77	30.57	36.52	5.63	65.81	45.40	11.04	31.01	**81.28**	12.38	37.79	53.27
	Trend slope	− 6.27	− 1.40	0.09	− 1.22	0.79	2.40	1.83	0.05	1.45	− 6.44	− 0.03	− **10.47**
Standard deviation	Trend length (mm)	25.46	**79.56**	14.86	16.72	48.14	20.48	5.34	25.94	40.16	14.02	43.44	18.10
	Trend slope	0.07	0.29	0.33	− 0.19	0.05	0.14	0.02	0.49	− 0.20	0.38	**1.80**	− 0.99
Mustafa Kemalpasa													
Arithmetic mean	Trend length (mm)	17.44	7.65	37.72	22.73	12.52	60.23	9.67	**74.21**	48.00	52.82	60.34	24.96
	Trend slope	− 8.97	2.69	0.14	0.73	0.45	1.58	− **32.22**	0.33	0.36	− 0.13	1.69	1.13
Standard deviation	Trend length (mm)	26.29	39.70	5.72	20.97	21.83	36.88	12.90	**49.58**	44.77	42.08	35.15	25.46
	Trend slope	0.28	0.38	2.03	− 0.01	0.43	1.08	− 3.96	0.52	− 0.14	0.20	− 6.98	− **18.53**

precipitation data of each station were calculated. After these analyses, the following evaluations were made:

- Since there is not a regular polygon in IPTA graphics for each station, it is seen that precipitation data varies by years.
- It is seen that this change increases in some stations and decreases in others.
- This increasing and decreasing variability emerges from climate change.
- Size of trend lengths and trend slopes shows how much variability there is between months. For example, for Bandirma Station, max. trend length is, respectively, 118.42 mm and 95.05 mm, and max. trend slope was calculated as −432 and 4.06. These values show that transition between two months is severe and it is seen that this violent transition is caused by climate change.

The following recommendations can be made to reduce this impact of climate change:

- The carbon emission values of existing industrial factories in the study area should be checked regularly.
- To minimize use of fossil fuels, local people should be made conscious of the facts and be encouraged to reduce their usage.
- As a result of industrialization brought about by increasing population, green residential areas that will decrease greenhouse gas levels should be increased.
- Awareness should be raised among future generations on the protection of nature through education.
- Protecting water resources in the study area and informing the public about water consumption is important in terms of reducing the effects of climate change.

DATA AVAILABILITY STATEMENT

All relevant data are available from an online repository (https://www.mgm.gov.tr/).

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