Detecting Variability and Trends in Daily Rainfall Characteristics in Amman-Zarqa Basin, Jordan

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Abstract

Rainfall has a great spatial and temporal variability. This variability has been manifested in many regions by climate change phenomenon. In this paper, variability and trends in daily rainfall in Amman-Zarqa Basin in Jordan have been detected. A number of parameters have been tested namely; number of rainy days, duration of the wet season, maximum and average daily rainfall. The rainfall data sets consist of 15 rain gauge stations located in the basin. Trends detection is carried out using time series plots, and Mann-Kendall test. The analyses showed trend towards decreased duration of the wet season associated with decreased number of rainy days for most of the stations. Furthermore, there is an increasing trend in the maximum and average daily rainfall for most of the stations. However, results of Mann-Kendall test revealed that none of the parameters under study showed statistically significant trends.

Keywords: Amman-Zarqa basin, climate change, daily rainfall, Mann-Kendall tau coefficient, trend analysis, rainfall variability

1. Introduction

Variability in rainfall characteristics (type, amount, frequency, intensity and duration) is among the important climate change impacts. Rainfall variability affects water resources sustainability which includes the availability, management, and utilization of water resources. This in turn may affect ecosystems, land productivity, agriculture, food security, water quantity and quality, and human health (EPA, 2014). Therefore, detailed knowledge and analysis of rainfall regimes on different time scales are important prerequisites for enhancing the management of water, planning and designing of hydraulic structures to mitigate the negative effects of floods and droughts.

Many studies all over the world have been conducted to detect changing pattern and amounts of precipitation in the last decades. Mansell (1997) investigated the effect of climate change on rainfall trends and flooding risks in the west of Scotland. His study indicated that there is a significant increase in winter rainfall over the past 30 years.In addition, global climate predictions indicated that these trends are likely to continue for several decades with obvious implications for flooding risk as well as water supply.Brunetti et al. (2001) analyzed seasonal and annual precipitation and number of rainy days in northeastern Italy. Their results showed a negative trend in the number of wet days associated with an increase in the contribution of heavy rainfall events to total precipitation. Cook and Heerdegen (2001) studied rainy season in Australia and found out that the duration of the rainy and wet seasons in northern Australia decreases with increasing latitude. Their study also indicated that the timing and duration of these seasons were affected by the El Nino–Southern Oscillation (ENSO). Hsu (2004) conducted a test and analysis for change existence in rainfall data using different statistical methods. His analysis yielded consistent test results for most rainfall characteristics and geographic regions. Salami et al. (2010) carried out statistical and trend analysis on a number of hydro-meteorological variables obtained from Jebba Hydropower station including rainfall. In their analysis, rainfall was observed to have insignificant negative trend. Karmeshu (2012) studied trends in annual precipitation for nine states in the Northeastern United States using Mann-Kendall test. The Mann Kendall test demonstrated that there is an increasing trend in precipitation in only six states. Almazroui et al. (2012) studied the seasonal climatology of the Arabian Peninsula for the period 1979–2009.

In their study, they found out that, irrespective of season, rainfall insignificantly increased in the first period (1979–1993), and then significantly decreased in the second period (1994–2009). Arun et al. (2012) studied the changing trend of rainfall of a river basin of Orissa near the coastal region and observed overall insignificant changes in the area.

In Jordan, the variability of precipitation over the past years has been detected by many researches (Al-Ansari et al., 1999, Bani-Domi, 2005, Smadi et al., 2006, Ghanem, 2010). In addition, several researches have included the climate change phenomenon and evaluated its impact on rainfall variation in Jordan (Cohen and Stunhill, 1996, Ragab and Prudhomme, 2002, Tarawneh and Kadioglu, 2008, Abandeh, 1999, Dahamsheh and Aksoy, 2007, Freiwana and Kadioglu, 2008, Hamdi et al., 2009, MoEnv, 2012, Matouqa, et al., 2013). Al-Ansari et al. (1999) analyzed the rainfall in the Badia region, and concluded that there was a general decrease in rainfall intensity. Tarawneh and Kadioglu (2002) conducted an analysis on precipitation records of 17 stations distributed according to climatic regions of Jordan. Their analysis showed the high variability of rainfall of the country. Bani-Domi (2005) conducted a trend analysis of seasonal and annual precipitation records in Jordan. His investigation concluded that none of the precipitation series showed significant trends; however, the slope estimates showed negative rates of change in the total annual rainfall for most stations. Smadi and Zghoul (2006) examined recent changes, trends, and fluctuations in the total rainfall and number of rainy days at three stations in Jordan. Their analysis showed a decline in the total rainfall and number of rain days in the second half of the past century. Freiwan and Kadioglu (2008) examined different meteorological factors including annual, seasonal, and monthly precipitation. Their results revealed insignificant, decreasing trend in precipitation. Hamdi et al. (2009) analyzed data from six meteorological stations distributed around the country using several parametric and nonparametric statistical approaches. Their results indicated that there are no visible trends indicating an increase or decrease in the annual precipitation. Ghanem (2010) analyzed data of the rainy season over a 50-year period for 11 stations distributed over Amman area. His analysis showed a decreasing trend of -0.4mm/year but with no statistical significance. Matouqa et al. (2013) studied the climate change implication on Jordan using GIS and artificial neural network for weather forecasting. Their results showed that no change has occurred in the mean annual rainfall in both northern and eastern part, while it has increased in the central region of Jordan.

However, although previous studies investigated precipitation trend in the country, these studies were concentrated mostly on annual scale analysis of rainfall records. Precipitation variability on different time scales, daily scale in particular, is important since annual values of precipitation may obscure short-period features in the rainfall pattern which in themselves might have great significance (Leopold, 1951). The variability in daily rainfall events of various sizes, the changes in rainfall frequency (represented by number of rainy days), and the length of the wet season may have important effect on the availability of water and vegetation, as well as, changes in total annual rainfall. On the other hand, in recent years the country experienced an increase in the unusual rainfall events of intense rainfall in a single-day that caused flash floods and considerable damage to human lives, houses, agricultural land, and infrastructure facilities in portion of the country. Hence it is of great significance to study how climate change phenomenon impacted the variability in the size and timing of daily rainfall events. This work aims at detecting the variability and trends in the characteristics of daily rainfall events in the basinrepresented by average daily rainfall, maximum daily rainfall, number of rainy days, and duration of the wet season in Amman Zarqa basin in Jordan.

2. Materials and Methods

2.1 Site and Data Description

Amman-Zarqa basin (AZB) is a vital basin in Jordan. It is located north-west of Jordan, and it is approximately 4710 km^2, 468 km^2 of which is in Syria. Within the AZB, is the most important aquifer which is Amman-Wadi Sir aquifer system (WRPS, 2000). Furthermore, the basin adjoins five of the densely populated governorates in Jordan including; Amman, Zarqa, Jarash, Balqa, and Marfaq (Al-Mashaqbeh et al., 2014). Hence about 60 % of the country’s population is living in the basin (Al-Omari et al., 2013).

This study is based on daily rainfall data available for 15 rainfall gauge stations distributed within AZB as shown in **Figure 1**. The data were compiled from databases that are maintained by Ministry of Water and Irrigation in Jordan. The 15 stations were selected according to data accuracy, availability, and adequate temporal coverage. The length of data records for these gauges ranges from 47-77 years. **Table 1** lists the name of each selected station, its ID, and its period of coverage.

2.2 Data Analysis

In this study, the longest records of daily rainfall data corresponding to 15 selected stations located in AZB were analyzed to determine whether there is evidence of specific trends in the characteristics of daily rainfall events in the basin. Four parameters have been tested in this work namely; average daily rainfall, maximum daily rainfall, number of rainy days, and duration of the wet season. The trend analysis is performed using time series plots and Mann-Kendall test. The methods of analysis include MINITAB statistical software (2010) and Addinsoft's XLSTAT software (2014).

The first step in the analysis was to extract the required data from the raw daily records maintained by the Ministry of Water and Irrigation. The duration of the wet season is defined, in this work, as the time in days between the first and last rainfall events in any water year. The extracted parameters are then subjected to basic statistical and trend analyses to determine their variability in the basin.

The basic statistical analysis performed on the parameters considered in this study involves determination of the measures of central tendencies (mean and median), the measure of dispersion (standard deviation, SD), the measure of degree of symmetry in the distribution (skewness, SK), and the degree to which any data set is peaked (Kurtosis, KT).

The trend analysis is performed using time series plots and Mann-Kendall test. Time series plots are used to evaluate the variability in the selected parameters over time. For this part of the analysis, MINITAB statistical software is used to create the time series plots. Linear trend model has been selected to fit the time series plots for all the parameters considered in this work.

The Mann-Kendall test is a non-parametric statistical test that is widely used for trend detection in different applications (Paulin and Xiaogang, 2005). This test is often used to test for presence of an increasing or decreasing trend in the considered time series (Mann, 19450, Kendall, 1975, Gilbert, 1987). In this test, the null hypothesis H_o is tested against the alternative hypothesis H_1 where:
H_o: There is no trend in the data

H1: There is a trend in the data

According to the test, the null hypothesis (Ho) is rejected in favor of the alternative hypothesis (H1) at certain probability level (α).

The Mann-Kendall test is based on the calculation of Kendall's tau (τ) coefficient which measures the association between two ordinal variables. In this part of the study, Addinsoft's XLSTAT software is used to evaluate the trend in the selected parameters. Kendall's tau (τ) ranges from -1.0 to 1.0. A positive value indicates that the rankings of both variables increase together. A negative value, on the other hand, indicates that as the rank of one variable increases, the other decreases. If the two variables are independent, then the Kendall's tau is expected to be approximately zero (Abdi, 2007, Nelsen, 2001).

The following section presents the results of the trend analyses using time series plots and Mann-Kendall test

3. Results

3.1 Basic Statistics

The results of the basic statistical analysis for the parameters considered in this work are presented in Tables 2-5. As illustrated in Table 2, the mean of average daily rainfall in the basin ranges from 3.8 mm in station AL0059 to 15.4 mm in station AL0005. The mean maximum daily rainfall in the basin ranges from 17.36 mm in station AL0059 to 76.22 mm in station AL0005 as presented in Table 3.

As for the mean number of rainy days, and duration of the wet season in the basin, Table 4 illustrates that the number of rainy days ranges from about 26 days to 45 days. While, the duration of the wet season varies from 155 to 187 days (as shown in Table 5) distributed in general between the months of October and May of any water year.

The results revealed that the distribution for all the selected parameters is either positively skewed (when SK > 0) or negatively skewed (when SK < 0). On the other hand, the kurtosis values for the parameters indicated either a sharper than normal peak (when KT is positive), or flatter than normal peak distribution (when KT is negative).

3.2 Trend Analysis Using Time Series Plots

Time series plots demonstrate that there are no generalized trends in the parameters under study over the past years as shown in Figures 2 through 5. For example, linear trend analyses of maximum daily rainfall from throughout most of the stations (10 out of 15 stations) have shown a general increase in extreme daily rainfall events over the past years (Figure 2).

As for the average daily rainfall, the analysis did not detect a clear increasing or decreasing trend in all the stations as illustrated in Figure 3. In the contrary, some stations showed an obvious increasing trend (AL0002, AL0004, AL0018, AL0022, AL0027, AL0035, AL0045 and AL0047), while some stations showed a slight decreasing trend (AL005, AL0028, AL0048, and AL0059). The remaining stations showed no clear increasing or decreasing trend (AL0017, AL0019, and AL0036).

Linear trend analysis predicts a decreasing trend in the number of rainy days over the past years in all the stations except for station AL0048 (Figure 4). The decreasing trend was also detected in the duration of the wet season at all the stations except for stations AL0005, AL0017, and AL0022 (Figure 5). The analysis revealed that variability in rainfall patterns led to an increase in the duration of dry periods in the past years.

3.3 Mann-Kendall Test

Tables 6 and 7 presents the results of the Mann-Kendall test, and null hypothesis test at 95% confidence level (α=0.05) on the selected parameters for the 15 stations considered in this work. As illustrated in Table 6, by running Mann-Kendall test on number of rainy days for the 15 stations, the test results in accepting the null hypothesis Ho for most of the stations except for stations; AL0004, AL0019, AL0035, AL0036, and AL0047. Accepting Ho indicates that there is no trend in the time series, and the result is statistically insignificant. On the other hand, the values of Kendall's tau (τ) were all negative except for stations; AL0022, AL0028, and AL0048 indicating that the number of rainy days decreases with time.

As for the duration of the wet season, results of Mann-Kendall test revealed that there is no trend in the series for all the stations (accepting the null hypothesis, Ho) except for two stations (AL0059 and AL0035) as indicated in Table 6. The values of Kendall's tau (τ) were all negative except for stations; AL0002, AL0005, AL0017, AL0018, and AL0022 indicating that the duration of the wet season decreases over the past years.

On running the Mann-Kendall test on maximum daily rainfall, the test revealed that there is no trend in the maximum daily rainfall series for most of the stations except for stations; AL002, AL0004, AL0005, AL0035, and AL0047 as shown in Table 7. The Kendall's Tau (τ) values, however, are positive for eight of the stations implying that the maximum daily rainfall increases with time.

Finally, for average daily rainfall data series, Mann-Kendall test revealed that no trends are statistically significant for most of the stations except for stations; AL002, AL0019, AL0027, AL0045, and AL0047. The Kendall's Tau (τ) values are positive for 10 stations in the basin, implying that the average daily rainfall increases in general over the past years (Table 7).

According to the observed decrease in number of rainy days and duration of the wet season, a special plan should be considered for water and agriculture management to overcome the severity of dry periods. On the other hand, with the general increase in occurrence of extreme precipitation events over the past years, the vulnerability for flood risks might be aggravated in the future and consequently resulted in problems in the water storage structures, sewer systems, and ineffectiveness in the performance of the waste water treatment systems existed in the basin. Hence, understanding rainfall variability and trends in this variability is necessary to help policymakers in managing water effectively in the country.

4. Conclusion

Rainfall variability is an important feature of semi-arid climates, and climate change is likely to increase this variability in many of these regions. In this paper, the variability in four parameters including; number of rainy days, duration of the wet season, maximum daily rainfall, and average daily rainfall in Amman-Zarqa basin are examined. Linear trend and Mann-Kendall test have been used in this paper to detect the variability and trends in these parameters. The results showed gradients in rainfall and rainfall variability across the basin. However there was no conformity in the results obtained from the two tests.

The trend lines in general identify a trend towards decreased number of rainy days throughout the basin, which is associated with decrease in the duration of the wet season. Mann-Kendall test, on the other hand, demonstrated that none of the parameters under study showed a generalized trend in all the station (at 5% significance level). The paper discusses the continuous need for detecting rainfall variability, and trends in this variability to help policymakers in managing water effectively in Amman-Zarqa basin. Continuous timely measures can certainly help in conducting such studies and serve in accurately identifying the impact, if any, of climate change phenomenon.

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References

Abandeh,A. (1999). Climate trends and climate change scenarios, vulnerability and Adaptation to Climate Change in Jordan, Project No. JOR/95/G31/IG/99, 1, Al-Shamil Engineering: Amman, Jordan.

Abdi,H. (2007). Kendall rank correlation, in Salkind, N.J. Encyclopedia of Measurement and Statistics, Thousand Oaks, CA.

Addinsoft's XLSTAT 2014.3.07, (2014).addinsoft. http://www.xlstat.com. Copyright Addinsoft, 1995-2014

Al-Ansari, N., Salameh, E., & Al-Omari, H. (1999).Analysis of rainfall in the Badia region, Jordan, Research Paper, 1. Al-al-Bayt University, Jordan.

Al-Mashaqbeh,O., A. Jiries, A., & El-Haj Ali, Z. (2014) Stormwater runoff quality generated from an urban and rural area in Amman Zarqa Basin, WIT Transactions on Ecology and the Environment, (182), 379-390.

Almazaroui, M., Nazrul Islam, M., Jones, P.D., Athar, H., &Ashfaqur Rahman, M. (2012). Recent climate change in the Arabian Peninsula: Seasonal rainfall and temperature climatology of Saudi Arabia for 1979–2009, Atmospheric Research, 111, 29–45.

Alomari, A., Al-houri, Z., &Weshah, R. (2013). Impacts of the As Samra waste water treatment plant upgrade on the water quality (COD, electrical conductivity, TP, TN) of the Zarqa river. Water Science and Technology, 67(7), 1455- 1464.

Arun,M.,Kundu,S., &MukHopadhyay, A. (2012) Rainfall trend analysis by Mann-Kendall test: A case study of north-eastern part of Cuttack district, Orissa. International Journal of Geology, Earth and Environmental Sciences, 2(1), 70-78.

Bani-Domi,M. (2005).Trend analysis of temperatures and precipitation in Jordan, Umm Al-Qura University Journal of Educational, Social Sciences & Humanities, 17(1), 15-36.

Brunetti, M.,Maugeri, M., &Nanni, T. (2001).Changes in total precipitation, rainy days and extreme events in northeastern Italy, International Journal of Climatology, 21, 861–871.

Cohen,S., &Stunhill, G.(1996).Contemporary climate change in the Jordan Valley. Journal of Applied Meteorology, 35, 1051–1058.

Cook, G., &Heerdegen, R. (2001). Spatial variation in the duration of the rainy season in monsoonal Australia, International Journal of Climatology, 21, 1723–1732.

Dahamsheh,A., &Aksoy, H. (2007).Structural characteristics of annual precipitation data in Jordan. Theoretical Applied Climatology, 88, 201–212.

EPA United States Environmental Protection Agency, (2014), Available: http://www.epa.gov/climatechange/impacts-adaptation/index.html(Aug/08/2014).

Freiwana, M., &Kadioglu, M. (2008).Climate variability in Jordan, International Journal of Climatology, 28, 69–89.

Hamdi, M., Abu-Allaban, M., Al-Shayeb, A.,Jaber, M., &Momani, N. (2009).Climate change in Jordan: A comprehensive examination approach, American Journal of Environmental Sciences, 5 (1), 58-68.

Hsu, H.(2004). Test and analysis for change existence in rainfall data, master's thesis, Department of Bioenvironmental Systems Engineering, National Taiwan University.

Ghanem, A. (2010). Climatology of the areal precipitation in Amman/Jordan, International Journal of Climatology, 31(9), 1328-1333.

Gilbert, R. (1987) Statistical methods for environmental pollution monitoring, 1987, Wiley, NY. Paulin, C.,&Xiaogang, S. (2005).Identification of the Effect of Climate Change on Future Design Standards of Drainage Infrastructure in Ontario, Ontario, Canada.

Karmeshu, N. (2012). Trend detection in annual temperature & precipitation using the Mann Kendall test – A case study to assess climate change on select states in the northeastern United States, master's thesis, Department of Earth and environmental Science, University of Pennsylvania.

Kendall,M. (1975). Rank correlation methods, 4th edition, Charles Griffin, London.

Leopold, L. (1951). Rainfall frequency: an aspect of climate variation, Transaction American Geophysical Union, 32(3), 347-357.

Mann, H. (1945).Non-parametric tests against trend, Econometrica, 13, 163-171.

Mansell, M. (1997).The effect of climate change on rainfall trends and flooding risk in the west of Scotland, Nordic Hydrology, 28, 37-50.

Matouqa,M., El-Hasan,T., Al-Bilbisi, H., Abdelhadi, M., Hindiyeh, M., Eslamian, S., &Duheisat, S. (2013). The climate change implication on Jordan: A case study using GIS and Artificial Neural Networks for weather forecasting, Journal of Taibah University for Science, 7, 44–55.

Minitab 17, (2010). Statistical Software, Computer software], 2010, State College, PA: Minitab, Inc. (www.minitab.com)

MoEnv (2012).Assessment of direct and indirect impacts of climate change scenarios on water availability and quality in the Zarqa River Basin. Water Resources study, 1, Amman, Jordan.

Nelsen, R. (2001). Kendall tau metric, Hazewinkel, Michiel, Encyclopedia of Mathematics, Springer.

Ragab, R., &Prudhomme, C. (2002).Climate change and water resources management in arid and semi-arid regions: prospective and challenges of the 21st century, Biosystem Engineering 81(1), 3–34.

Salami, A., Raji,M., Sule,B.,Abdulkareem,Y., &Bilewu,S. (2010). Impacts of climate change on the water resources of Jebba hydropower reservoir, Proc. International Conf. on Sustainable Urban Water Supply in Developing Countries, University of Ilorin, Nigeria, 298-312.

Smadi, M., &Zghoul, A. (2006).A sudden change in rainfall characteristics in Amman, Jordan during the mid 1950s, American Journal of Environmental Sciences, 2 (3), 84-91.

Tarawneh,Q. &Kadioglu,M. (2002).An analysis of precipitation climatology in Jordan.Theoretical.Applied Climatological, 1–14.

WRPS, (2000).Ministry Of Water and Irrigation, Water Resource Policy Support Groundwater Management Component Outline Hydrogeology of the Amman-Zarqa Basin.

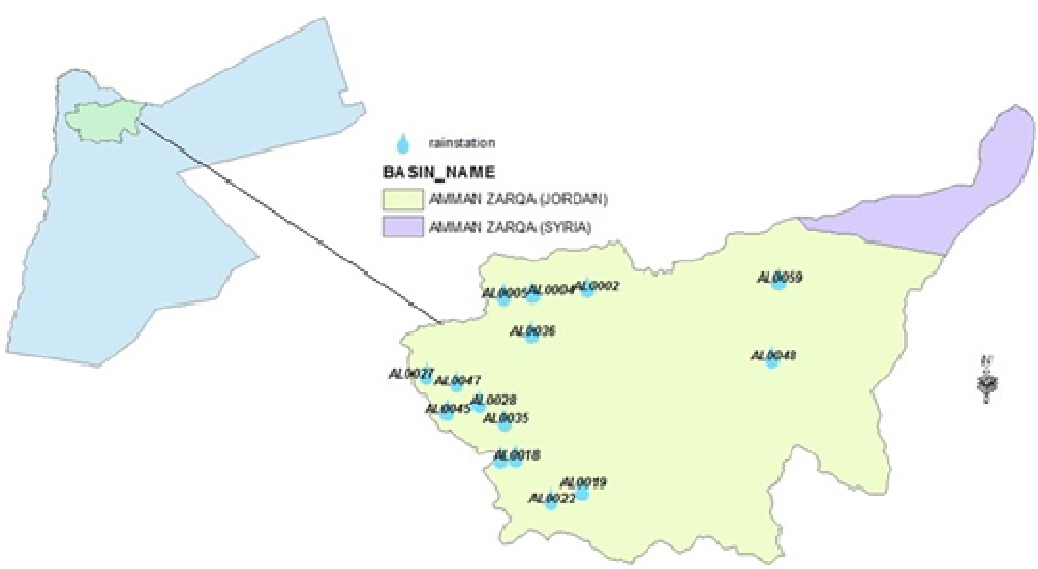

Figure1: Location of Amman-Zarqa basin in Jordan, and the Distribution of the Selected Rain Gauge Stations within the Basin

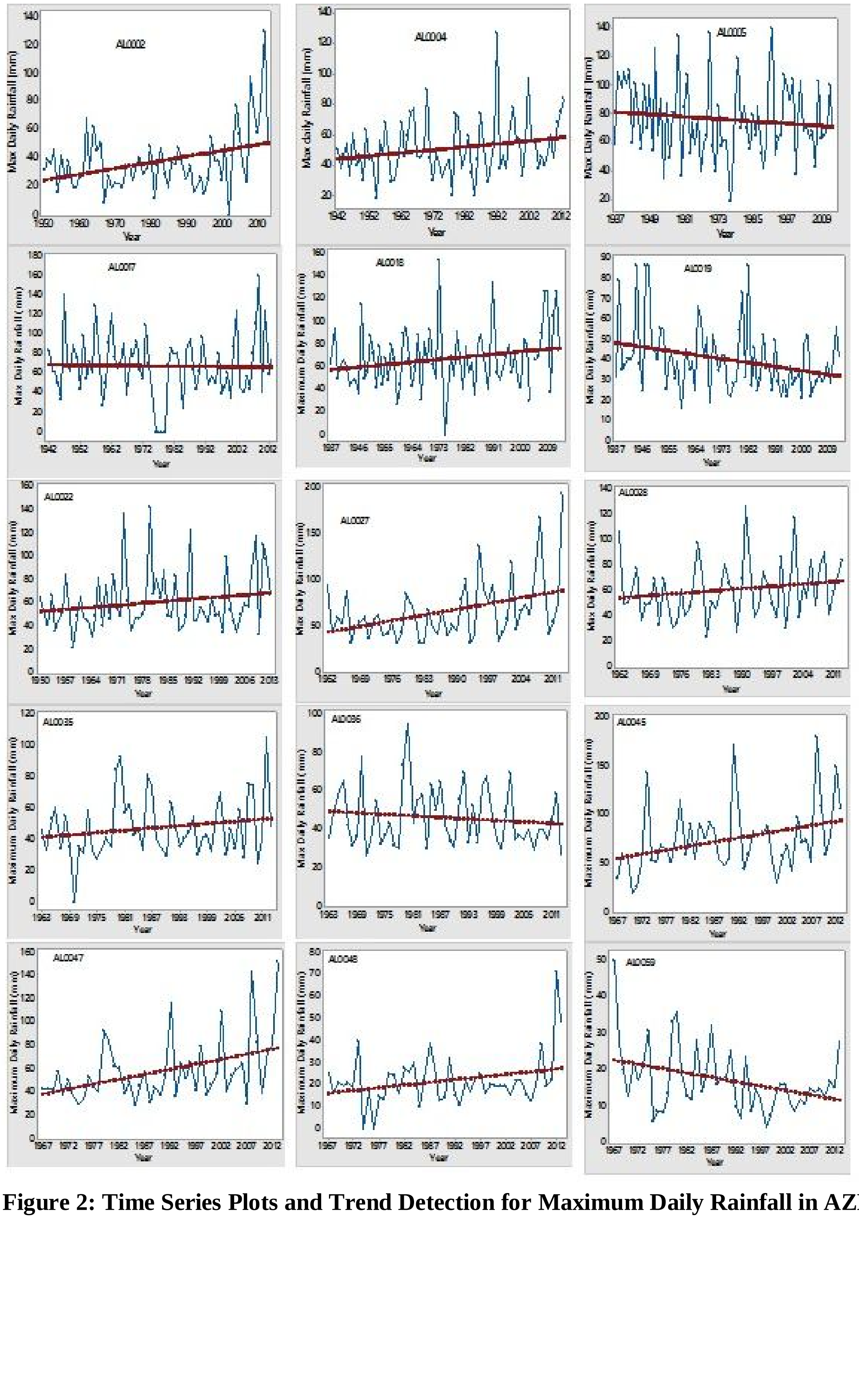

Figure 2: Time Series Plots and Trend Detection for Maximum Daily Rainfall in AZB

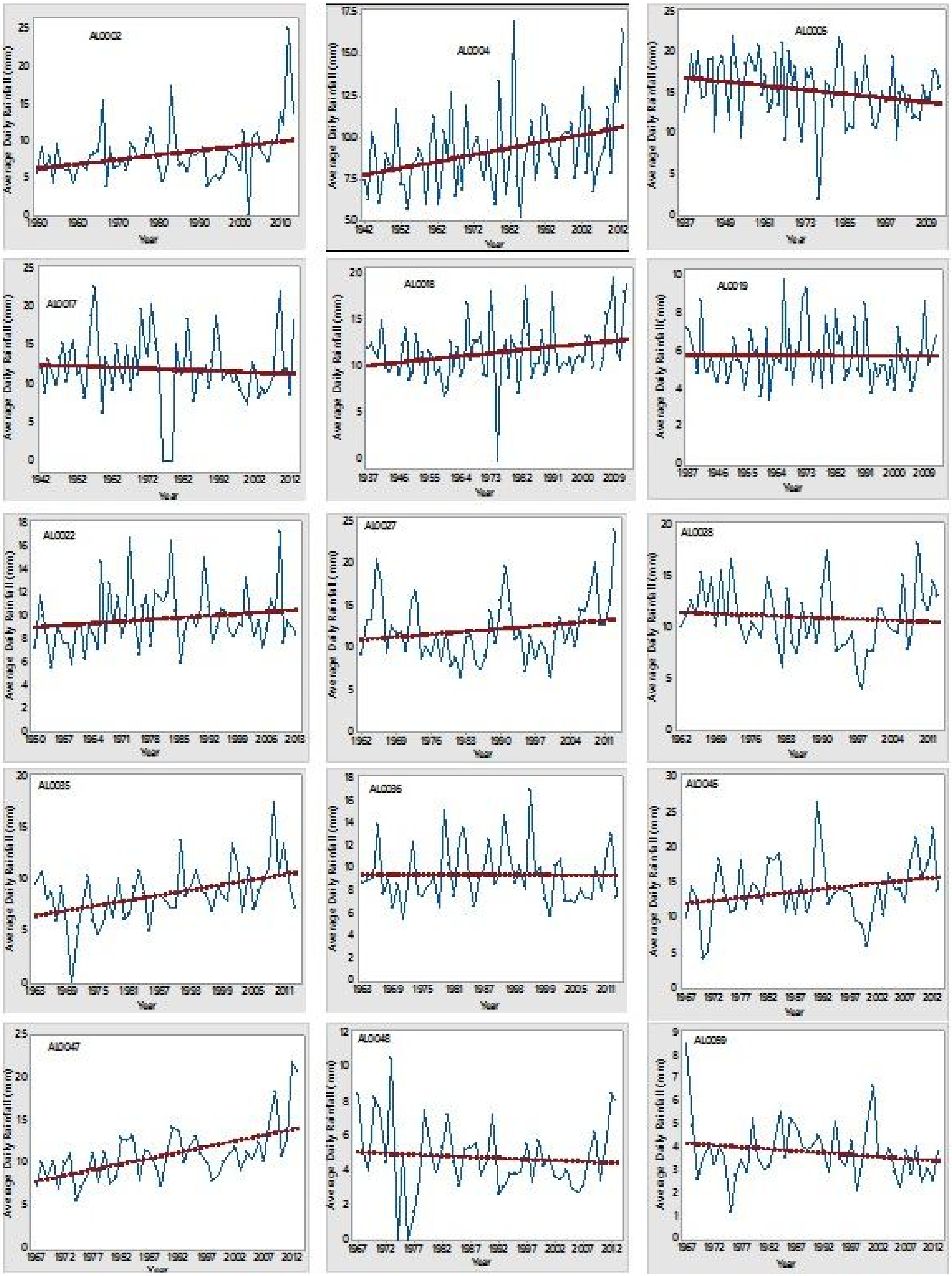

Figure 3: Time Series Plots and Trend Detection for Average Daily Rainfall in AZB

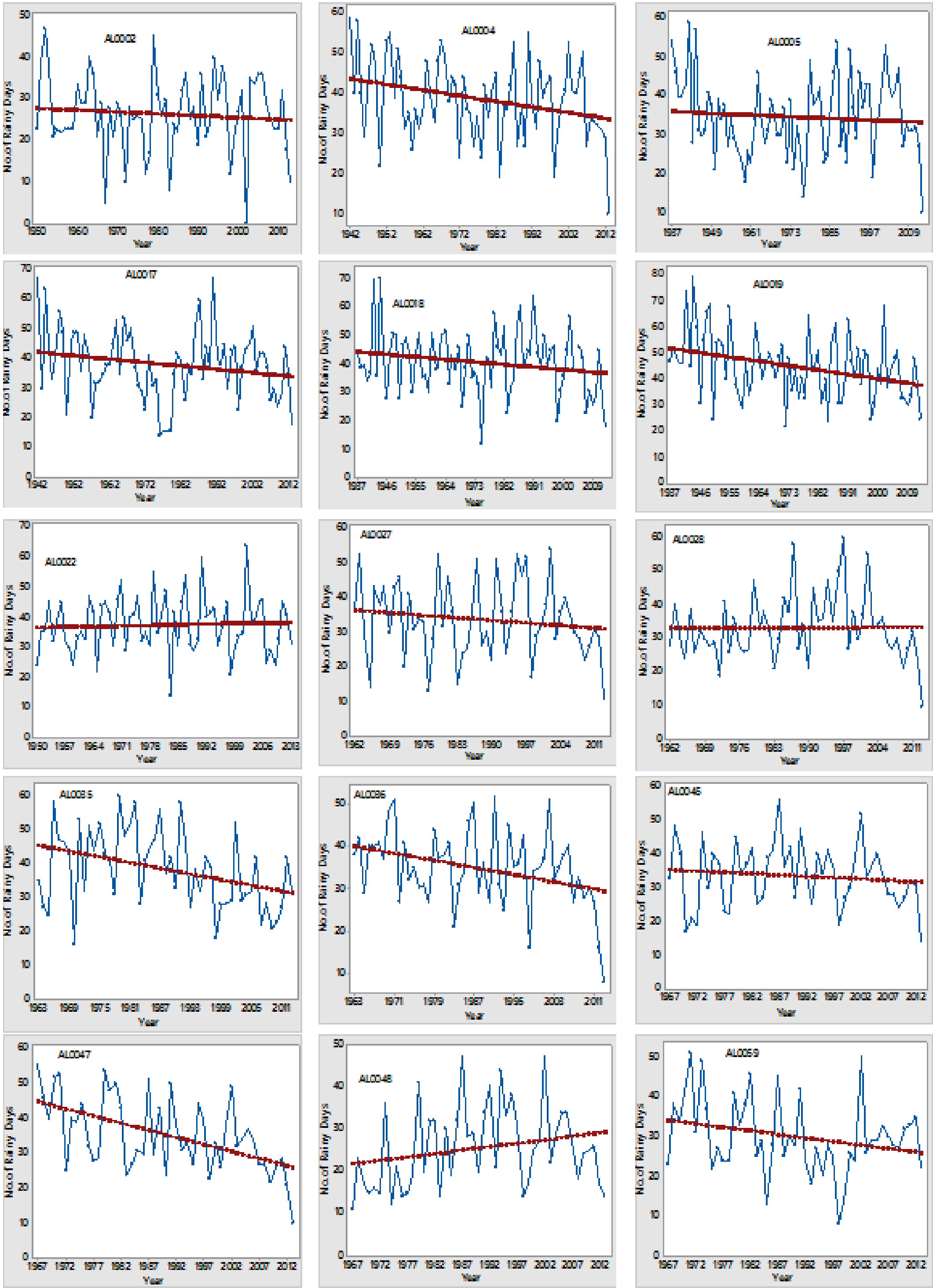

Figure 4: Time Series Plots and Trend Detection in Number of Rainy Days in AZB

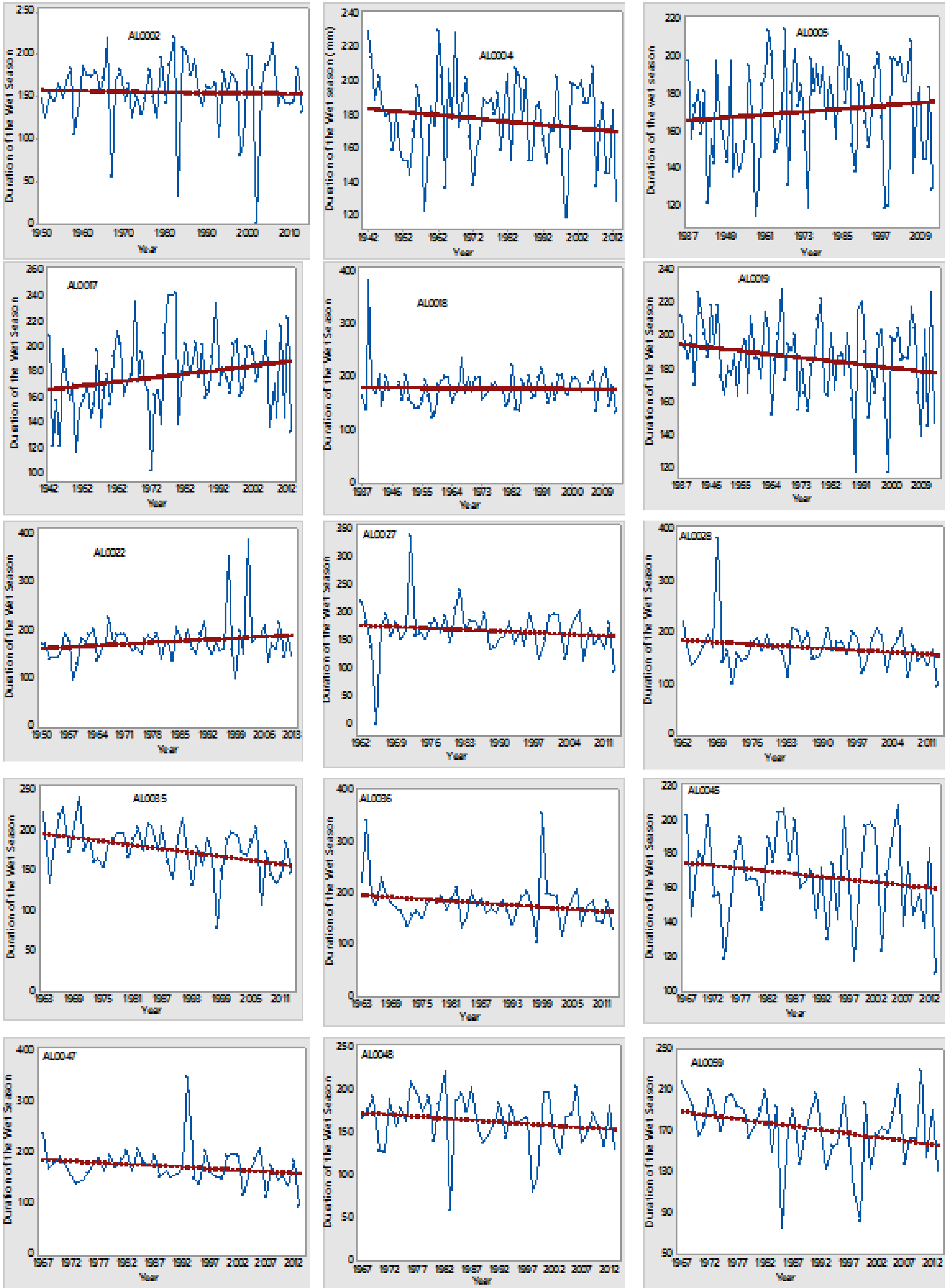

Figure 5: Time Series Plots and Trend Detection in Duration of the Wet Season in Selected Stations in AZB

Table 1: Names, ID's and Data Availability for the Selected Rain Stations in AZB

Station ID	Station Name	Period of Record
AL0002	Midwar	1950-2013
AL0004	Jarash	1942-2013
AL0005	Kitta	1937-2013
AL0017	Sweilih	1942-2013
AL0018	Jubeiha	1937-2013
AL0019	Amman Airport	1937-2013
AL0022	Amman Hussein College	1950-2013
AL0027	Subihi	1962-2013
AL0028	Rumeimin	1962-2013
AL0035	K.H. nursery Evaporation Station (Baq'a)	1963-2013
AL0036	Prince Feisal Nursery	1963-2013
AL0045	Um Jauza	1967-2013
AL0047	Sihan	1967-2013
AL0048	Khaldiya	1967-2013
AL0059	Um el Jumal Evaporation Station	1967-2013

Table 2: Summary Basic Statistics for Average Daily Rainfall (Mm) in AZB

Station ID	Mean (mm)	Median (mm)	Max (mm)	SD	SK	KT	Number of Elements
AL0004	9.2	8.9	17.0	2.4	1.0	1.4	72
AL0005	15.4	15.6	22.0	3.8	-0.6	0.7	77
AL0017	12.0	11.8	22.6	4.5	-0.4	1.6	72
AL0018	11.6	11.0	19.6	3.1	0.2	2.4	77
AL0019	5.8	5.6	9.8	1.4	0.8	0.4	77
AL0022	9.9	9.5	17.3	2.5	1.1	1.4	64
AL0027	12.2	11.7	23.9	3.8	1.0	1.0	52
AL0028	11.1	10.6	18.3	3.1	0.3	-0.1	52
AL0035	8.7	8.7	17.5	2.8	0.3	2.5	51
AL0036	9.5	9.1	17.1	2.6	1.0	0.7	51
AL0045	14.1	14.0	26.4	4.3	0.3	1.0	47
AL0047	11.0	10.9	21.7	3.2	1.4	3.1	47
AL0048	4.8	4.6	10.5	2.1	0.3	0.7	47
AL0059	3.8	3.6	8.5	1.2	1.3	4.1	47

Table 3: Summary Basic Statistics for the Maximum Daily Rainfall (mm) in AZB

Station ID	Mean (mm)	Median (mm)	Max (mm)	SD	SK	KT	Number of Elements
AL0002	38.0	35.0	130.0	21.5	1.8	5.0	64
AL0004	51.4	47.0	127.0	18.7	1.2	2.9	72
AL0005	76.2	71.0	140.0	26.4	0.4	-0.4	77
AL0017	68.1	65.1	159.7	31.6	0.2	0.7	72
AL0018	67.4	65.4	155.0	27.1	0.8	1.3	77
AL0019	40.4	37.2	87.0	16.5	1.3	1.7	77
AL0022	61.5	52.0	143.5	25.5	1.4	1.9	64
AL0027	66.8	57.0	194.0	33.7	1.8	4.0	52
AL0028	61.6	60.0	126.0	22.5	0.8	0.6	52
AL0035	48.0	43.2	106.6	19.6	0.8	1.1	51
AL0036	46.3	42.2	95.0	15.6	0.9	0.4	51
AL0045	75.1	68.2	180.0	34.7	1.3	1.8	47
AL0047	58.4	51.0	152.0	27.7	1.8	3.5	47
AL0048	22.0	19.8	71.5	11.7	1.8	6.6	47
AL0059	17.4	15.0	50.0	8.9	1.4	2.7	47

Table 4: Summary Basic Statistics for the Number of Rainy Days (Days) in AZB

Station ID	Mean	Median	Max	SD	SK	KT	Number of Elements
AL0004	39	39	59.0	10.0	-0.2	0.0	72
AL0005	35	34	59.0	10.0	0.2	-0.1	77
AL0017	38	38	67.0	11.7	0.2	0.2	72
AL0018	41	40	70.0	11.1	0.2	0.6	77
AL0019	45	45	79.0	12.3	0.5	0.0	77
AL0022	38	37	64.0	9.5	0.3	0.4	64
AL0027	34	33	54.0	11.2	0.1	-0.5	52
AL0028	33	32	60.0	9.7	0.7	1.1	52
AL0035	38	39	60.0	11.5	0.1	-0.9	51
AL0036	35	35	52.0	9.1	-0.4	0.7	51
AL0045	34	34	56.0	9.4	0.1	-0.3	47
AL0047	36	33	55.0	10.5	0.1	-0.6	47
AL0048	26	25	47.0	9.7	0.5	-0.6	47
AL0059	30	28	51.0	9.4	0.3	0.3	47

Table 5: Summary Statistics for the Duration of the Wet Season (Days) in AZB

Station ID	Mean (Days)	Median (Days)	Max (Days)	SD	SK	KT	Number of Elements
AL0002	155	160	220	40.6	-1.5	3.6	64
AL0004	177	182	230	25.6	-0.3	-0.3	72
AL0005	171	174	215	26.2	-0.4	-0.8	77
AL0017	178	175	243	30.6	0.1	-0.1	72
AL0018	180	179	383	33.9	2.8	16.0	77
AL0019	187	188	229	24.1	-0.6	0.3	77
AL0022	178	174	390	43.6	2.8	12.0	64
AL0027	169	169	341	44.2	0.0	7.2	52
AL0028	172	169	383	41.6	2.3	12.3	52
AL0035	177	176	242	30.5	-0.7	1.2	51
AL0036	181	178	357	43.0	2.2	8.2	51
AL0045	168	168	209	26.0	-0.3	-0.6	47
AL0047	174	171	350	37.6	2.0	9.9	47
AL0048	164	168	224	33.0	-1.0	1.5	47
AL0059	173	174	230	33.1	-1.0	1.2	47

Table 6: Results of Mann-Kendall test for number of rainy days, and duration of the wet season in AZB

Station ID	Number of Rainy Days			Duration of the Wet Season		
	Kendall's -τ	p-value	Test Result	Kendall's -τ	p-value	Test Result
AL0002	-0.018	0.839	Accept H_o	0.014	0.871	Accept H_o
AL0004	-0.187	0.022	Reject H_o	-0.088	0.278	Accept H_o
AL0005	-0.034	0.669	Accept H_o	0.084	0.287	Accept H_o
AL0017	-0.133	0.103	Accept H_o	0.154	0.058	Accept H_o
AL0018	-0.121	0.126	Accept H_o	0.044	0.579	Accept H_o
AL0019	-0.231	0.003	Reject H_o	-0.106	0.178	Accept H_o
AL0022	0.020	0.821	Accept H_o	0.070	0.417	Accept H_o
AL0027	-0.117	0.229	Accept H_o	-0.119	0.218	Accept H_o
AL0028	0.007	0.950	Accept H_o	-0.067	0.492	Accept H_o
AL0035	-0.274	0.005	Reject H_o	-0.232	0.017	Reject H_o
AL0036	-0.225	0.022	Reject H_o	-0.147	0.131	Accept H_o
AL0045	-0.098	0.339	Accept H_o	-0.111	0.279	Accept H_o
AL0047	-0.367	0.0003	Reject H_o	-0.160	0.117	Accept H_o
AL0048	0.157	0.125	Accept H_o	-0.133	0.193	Accept H_o
AL0059	-0.111	0.283	Accept H_o	-0.265	0.009	Reject H_o

Table 7: Results of Mann-Kendall Test for Average and Maximum Daily Rainfall in AZB

Station ID	Average Daily Rainfall			Maximum Daily Rainfall		
	Kendall's -τ	p-value	Test Result	Kendall's -τ	p-value	Test Result
AL0002	0.24	0.005	Reject H_o	0.192	0.026	Reject H_o
AL0004	0.239	0.003	Reject H_o	0.116	0.154	Accept H_o
AL0005	-0.184	0.018	Reject H_o	-0.066	0.398	Accept H_o
AL0017	-0.100	0.215	Accept H_o	-0.049	0.547	Accept H_o
AL0018	0.132	0.090	Accept H_o	0.101	0.196	Accept H_o
AL0019	-0.001	0.996	Accept H_o	-0.166	0.034	Reject H_o
AL0022	0.101	0.242	Accept H_o	0.110	0.200	Accept H_o
AL0027	0.113	0.243	Accept H_o	0.226	0.019	Reject H_o
AL0028	-0.086	0.372	Accept H_o	0.126	0.193	Accept H_o
AL0035	0.292	0.003	Reject H_o	0.091	0.350	Accept H_o
AL0036	-0.009	0.935	Accept H_o	-0.061	0.537	Accept H_o
AL0045	0.149	0.143	Accept H_o	0.239	0.018	Reject H_o
AL0047	0.388	< 0.0001	Reject H_o	0.253	0.013	Reject H_o
AL0048	-0.089	0.384	Accept H_o	0.092	0.369	Accept H_o
AL0059	-0.106	0.298	Accept H_o	-0.185	0.069	Accept H_o