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1st Int. Congress on Biosystems Engineering 2019 **ARAŞTIRMA MAKALESİ/RESEARCH ARTICLE**

Mapping spatio-temporal tendencies of climate types in Geographic Information Systems (GIS) media: A case study in Şanlıurfa and its environs

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Ö Z E T / A B S T R A C T

Aims: The primary objective of this study was to figure out spatio-temporal tendencies of climate-types in Şanlıurfa town and its environs, located in the Southeastern Anatolia Project (GAP) area, through using Erinç Drought Index method.

Methods and Results: Data sets consisting of long-term (1965-2018) annual total precipitation as well as average annual maximum temperature series of Şanlıurfa, Birecik, Akçakale, Ceylanpınarı, Siverek and Bozova meteorological stations -distributed unevenly over total surface area of 19 242 km²- were obtained and utilized in order to calculate *Erinç Drought Index (EDI)* on a yearly basis. *EDI* time series of each station was divided into three non-overlapping and successive parts or periods, i.e. *period-1* (1965-1981), *period-2* (1982-1999), *period-3* (2000-2018). The best fitting probability distribution models to the *EDI* series of each period were, in turn, determined by performing a regular frequency analysis procedure by *Kolmogorov-Smirnov Goodness of Fit Test* at the 5% significance level. *EDI* having 50% probability was estimated for the three periods of each station by utilizing probability models determined exclusively for each predetermined period. Afterwards, regular grids with the size of 100 m by 100 m were established over the study area in *GIS* media. *Ordinary-Kriging* interpolation technique was employed to estimate index values at the grid points and to generate climate maps over the study area for the three successive periods.

Conclusions: Based on the spatio-temporal tendencies map of climate types for 3 time periods, it was concluded that the spatio-temporal climatic characteristics of Şanlurfa province is dominated as "*Arid*", "*Semi-arid*" and "*Sub-humid*" climate type from south to north, respectively, and areas of severe drought exposure expands northward along to Siverek in all three periods.

Significance and Impact of the Study: Although Atatürk, Birecik, and Karkamış Dams tackle to mitigate drought expansion in the northwest, it is unlikely that it would prevent the spread of the future drought drifts because of global warming. It is strongly recommended that spatio-temporal climate change studies should be periodically conducted in tandem with forest management practices for the whole *GAP* area.

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INTRODUCTION

The average weather conditions that persist over a region for many years are known as climate. In recent decades, changes in climate have caused adverse impacts on natural and human systems in the continents and across the oceans (Anonymous, 2014). The atmosphere and oceans have warmed, sea levels have risen, and glaciers and ice sheets, in turn, have decreased in size. The best available evidence of climate change is unexpected high temperatures, and the main cause of it is ever increasingly greenhouse gas (GHG) emissions induced by human activities (Anonymous, 2015). For millennia, atmospheric carbon dioxide concentration has never been above 300 parts per million (ppm) up until 1950 (Anonymous, 2019a). The greenhouse gas concentrations reached new highs, globally averaged mole fractions of CO^2 at 405.5 ppm. This, in turn, has had a significant impact on temperature variations. Mankind experienced the fourth warmest year on record between 2015-2018 as the long-term warming trend has continued nowadays. Increases in average global temperatures are expected to be within the range of 3°C to 5°C by 2100 (Anonymous, 2019b). Even if the global warming of an increase above 1.5°C would bring far higher risks to health, livelihoods, food security, water supply, human security and economic growth (Anonymous, 2018), humanity should find ways of getting used to deleterious effects of global warming. Expansion of drought prone areas, as experienced recently in Turkey, has been the result of climate change. According to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), Turkey is located in the Mediterranean Basin that is especially vulnerable to the adverse impacts of climate change (Anonymous, 2012). Almost all available studies agreed that Turkey will have significant climate change-induced problems such as the decrease in water quantity and quality, decreasing precipitation amounts, rising annual temperatures, increases in frequency and magnitude of the extreme weather events including floods and droughts (Tonkaz, 2006; Tayanç et al., 2009; Anonymous, 2011; Yılmaz and Imteaz, 2014; İrvem et al., 2018). Despite the existence of an ongoing series of activities to research the potential results of global climate change on a water-basin scale for river basins that are socio-economically important for Turkey, there is, undoubtedly, a need for more scientific studies on these issues (Anonymous, 2011). In turn, according to climate change projections regarding Turkey, it was anticipated that precipitation will have decreased remarkably in all river basins of Turkey in the period of 2016-2099. Furthermore, it is emphasized that the twin-river basins, i.e. Euphrates and Tigris basins, in Southeastern Anatolia will be affected mostly by climate change (Demircan et al., 2017). In this context, long dry spells are expected in the Southeastern Anatolia Region in the future, and this will, in turn, affect different sectors (Birpınar and Tuğaç, 2018), particularly agriculture. Moreover, the Southeastern Anatolia Project –one of the largest regional development projects in Turkey, known universally as GAP (Cetin, 2020)– was planned in this region. The effects of climate change are reflected in air temperature and precipitation, which have a major impact on crop growth and yields. These implications have posed water-related problems in the GAP area of potentially 1.78 Mha irrigable agricultural areas, of which 0.53 Mha has been presently under irrigation (Cetin, 2020). Extent and severity of problems is of spatio-temporal characteristics. Therefore; determining the spatio-temporal tendencies of climate types at different periods is of prime importance for monitoring climate change in the GAP area. Many methods have been developed to determine the climate class of a region. However, each method has its own limitation, strengths as well as weaknesses to use under different climatic conditions. Erinç Drought Index, Percentage of Normal Index, Standard Precipitation Index, Palmer Drought Severity Index, Thornthwaite and De Martonne methods (Aktaş et al., 2018) are among the frequently used ones in regional climate classification studies in Turkey. Important information on the magnitude, severity, frequency and areal extent of the drought can be derived from those indices (Mishra and Singh, 2010). There is doubt that spatio-temporal tendencies of climate classes needs to be determined for different successive periods in order to make reasonable inferences about regional changes in climate.

Staple objectives of this research were two-fold–namely, to develop Erinç Drought Index maps with the 50% probability level for the three predetermined sequential time periods as well as to figure out spatio-temporal tendencies of climate-types in Şanlıurfa town and its environs.

MATERIAL and METHODS

Materials

This study was carried out in Şanlıurfa town and its environs, covering 19 242 km² area (Anonymous, 2019c), located in the Southeastern Anatolia Project (GAP) area. Long-term (1965-2018) annual total precipitation and annual maximum temperature series of Şanlıurfa, Birecik, Akçakale, Ceylanpınarı, Siverek and Bozova meteorological stations were utilized in the study (Figure 1). Geo-referencing of meteorological stations was rendered possible by using universal transverse Mercator (UTM) projection system with the datum of WGS84.

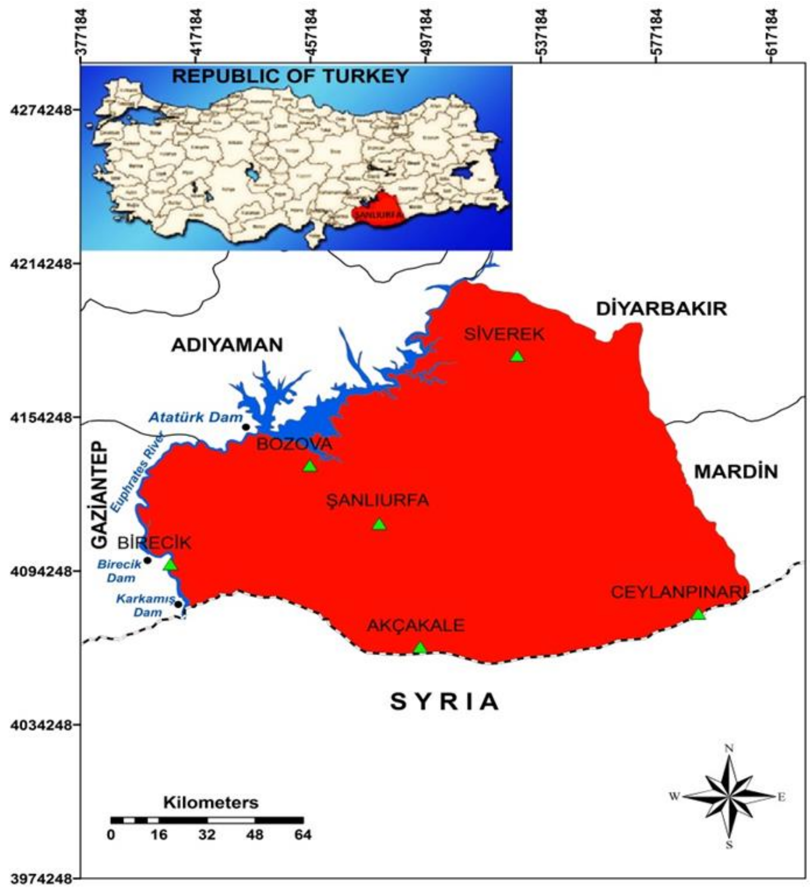

Figure 1. Location of the study area in Turkey

Methods

Erinç drought index (EDI)

Erinç (1965) has developed a simple drought indicator for Turkey to describe the drought problem for arid/humid area and duration separation purposes. In his formulation, annual total precipitation and annual average maximum temperature –which is supposed to cause water deficiency due to evaporation– are used to drive the index. Climate classification due to Erinç drought index (EDI or Im) is done by considering index values given in Table 1 (Türkeş and Akgündüz, 2011; Sen, 2015; Li et al., 2017; Celik and Gülersoy, 2018). In this research, Erinç Drought Index was computed for each year in turn by using Equation 1, and then EDI time series of each station was divided into three non-overlapping and successive parts or periods, i.e. period-1 (1965-1981), period-2 (1982-1999), period-3 (2000-2018).

$$I_m = \frac{P}{T_{\max\_mean}} \quad \text{Eq. (1)}$$

where;

I_m: Erinç drought index,

P: Annual total precipitation (mm),

T_{max_mean}: Annual average maximum temperature (°C).

Table 1. Erinç classification (Haider and Adnan, 2014; Sen, 2015)

Climate Classification	Index Value (I_m)	Vegetation Cover
Severe arid	<8	Desert
Arid	8-15	Desertification
Semi-arid	15-23	Arid
Sub-humid	23-40	Forest
Humid	40-55	Moist forest
Very humid	>55	Very moist forest

Frequency analysis

In order to include uncertainty into the study, EDI is tried to be predicted from the probability models of each station. To this end, frequency analysis for Erinç Precipitation Efficiency Index series of stations for the predetermined periods in turn were performed through using BestFit software (Anonymous, 2004). The best-fit probability distribution models were determined by using Kolmogorov-Smirnov goodness-of-fit test at 5% significance level. With the help of "the frequency factor equation" (Chow et al., 1988), EDI for 50% probability level, which is specific for this study, is estimated individually for each station (Equation 2).

$$X_{50\%} = \overline{X} + K_{50\%} S \qquad \text{Eq. (2)}$$

where;

S: Standard deviation,

$\overline{x}$: Mean of the data set subjected to frequency analysis,

$X_{50\%}$: Expected value of the variable at the 50% probability level,

$K_{50\%}$:Frequency factor of the probability model, which is a property of the frequency distribution given at 50% probability level.

Geostatistical analysis

In order to delineate the spatial extent of a variable at the hand, geostatistical interpolation methods (Cetin, 1996) might be a useful tool. To that end, ordinary kriging (OK) interpolation technique has been adopted in this study. The first and most important step in geostatistics is determine the spatial dependence structure, i.e. semivariogram function, of a regionalized variable. In hydrology and hydrometeorology, the most commonly used semivariogram functions are Spherical, Gaussian and Linear models. The resulting semivariogram is a measure of the spatial dependence of the semivariogram model (Tabios and Salas, 1985) which is used to predict values of the modeled attribute at unsampled locations. Kriging equation system (Burgess and Webster, 1980) is solved in order to make a best linear unbiased estimation at the un-sampled locations over the sampling domain (Cetin, 1996; Mert and Dağ, 2017; Anonymous, 2019d).

RESULTS and DISCUSSION

Computation of Erinç drought index series

The data sets consisting of the long-term (1965-2018) annual total precipitation and annual maximum temperature series were divided into three non-overlapping but consecutive periods as seen in Table 2. Erinç Drought Index (EDI or Im) on a yearly basis was computed for these periods and the index results by stations were presented in Table 2 as yearly time series. Due to the lack of meteorological data at Bozova station for the two successive periods of period-1 (1965-1981) and period-2 (1982-1999), Im (EDI) could not be computed on a yearly basis as seen in Table 2. In order to render meaningful Table 2, it should be gone through with climate classification given in Table 1. In turn, the higher the index values, the less drought episode in favor of humid climate type in the region.

Table 2. Erinç drought index (*Im*) series of meteorological stations

Periods/Subgroup	Year	Şanlıurfa	Birecik	Akçakale	Ceylanpınarı	Siverek	Bozova
Period-1 (1965-1981)	1965	20.8	19.4	13.4	10.7	23.7	N/A*
	1966	13.4	12.5	8.6	9.8	19.6	N/A
	1967	35.8	22.7	24.8	19.7	43.8	N/A
	1968	26.6	20.2	16.4	17.4	38.2	N/A
	1969	33.0	17.5	17.3	20.9	30.7	N/A
	1970	10.3	10.0	6.5	8.1	13.4	N/A
	1971	22.2	14.9	11.6	12.3	20.5	N/A
	1972	17.8	16.4	16.4	16.1	26.3	N/A
	1973	9.0	9.4	4.5	4.6	14.1	N/A
	1974	19.4	13.8	12.2	14.0	24.6	N/A
	1975	19.5	16.5	11.3	12.3	22.2	N/A
	1976	30.5	25.2	17.4	21.5	42.9	N/A
	1977	15.8	13.2	10.5	11.8	21.1	N/A
	1978	14.2	11.5	8.4	12.4	22.4	N/A
	1979	19.9	12.3	12.5	11.4	27.5	N/A
	1980	19.3	19.8	13.9	16.6	28.1	N/A
	1981	21.6	17.0	12.2	14.7	24.2	N/A

Continued Table 2.

	1982	15.0	11.4	9.8	13.5	24.1	N/A
	1983	21.8	14.4	11.5	12.6	25.4	N/A
	1984	15.9	13.2	7.1	7.9	26.8	N/A
	1985	19.3	14.8	10.5	11.9	27.4	N/A
	1986	18.1	12.2	8.3	10.4	21.5	N/A
	1987	22.5	13.9	12.8	14.7	36.4	N/A
	1988	30.8	21.5	16.2	19.4	37.3	N/A
	1989	12.4	8.9	8.4	7.1	16.3	N/A
Period-2 (1982-1999)	1990	10.7	10.5	8.1	6.4	16.2	N/A
	1991	18.3	13.5	10.7	10.2	24.9	N/A
	1992	17.3	12.2	9.0	12.1	23.3	N/A
	1993	20.4	13.0	15.2	10.6	30.5	N/A
	1994	21.1	16.8	12.7	16.2	31.9	N/A
	1995	10.9	9.5	8.7	8.0	21.0	N/A
	1996	35.2	23.9	18.6	19.0	39.4	N/A
	1997	19.0	14.7	10.7	10.3	29.7	N/A
	1998	16.5	12.5	8.0	8.5	24.1	N/A
	1999	11.6	9.1	6.7	7.4	14.4	N/A
	2000	15.5	12.6	10.2	7.7	22.2	14.8
	2001	21.9	18.9	14.2	11.5	31.5	20.4
	2002	13.2	9.6	9.8	8.7	16.5	13.4
	2003	20.9	17.0	13.3	13.0	31.5	21.1
	2004	20.7	17.7	11.0	12.4	25.7	17.9
	2005	13.6	11.3	8.2	6.7	20.3	14.2
	2006	14.2	14.0	8.6	14.9	27.0	16.7
	2007	14.6	15.5	7.6	12.5	21.7	12.3
	2008	12.3	7.8	6.2	4.1	18.9	10.4
Period-3 (2000-2018)	2009	18.2	15.9	9.8	8.6	31.7	16.7
	2010	10.4	9.3	4.4	5.6	21.9	10.8
	2011	18.3	15.9	10.7	9.1	31.4	24.4
	2012	24.8	21.2	12.2	8.8	30.9	23.3
	2013	16.1	11.8	7.6	8.8	19.1	13.8
	2014	16.0	7.7	11.8	10.2	19.6	18.2
	2015	15.5	13.8	8.1	8.8	24.4	14.3
	2016	12.4	9.1	7.4	8.2	23.1	11.6
	2017	7.5	7.0	8.0	4.5	15.2	13.3
	2018	28.1	19.1	23.7	13.0	32.9	25.2

[*] *Not Applicable* due to the lack of yearly data

Fitting probability distributions to EDI series

Frequency analysis was performed to EDI series – calculated by using annual total precipitation and mean annual maximum temperature series– based on the periods considered. The probability distribution function (PDF) of each data set was obtained by frequency analysis. Index values (EDI) having 50% probability level, i.e. recurrence interval of two-year, was estimated for the three periods of each station by utilizing PDFs determined exclusively for each predetermined period of stations. The probability distribution models determined for each period of stations and estimated Erinç drought indices with 50% probability level were summarized in Table 3.

Table 3. Best fitted *PDFs* for the stations and periods considered, and *Im* values of 50% probability level

Stations	Record Period	*PDFs*	*EDI (Im)*
Şanlıurfa	Period 1 (1965-1981)	Pearson Type 5	19.6
	Period 2 (1982-1999)	Logistic	18.1
	Period 3 (2000-2018)	Extreme Value	15.8
Birecik	Period 1 (1965-1981)	Logistic	15.8
	Period 2 (1982-1999)	Log-Logistic	12.9
	Period 3 (2000-2018)	Normal	13.4
Akçakale	Period 1 (1965-1981)	Log-Logistic	12.5
	Period 2 (1982-1999)	Inverse Gauss	9.8
	Period 3 (2000-2018)	Log-Logistic	9.4
Ceylanpınarı	Period 1 (1965-1981)	Extreme Value	13.1
	Period 2 (1982-1999)	Extreme Value	10.8
	Period 3 (2000-2018)	Extreme Value	8.9
Siverek	Period 1 (1965-1981)	Log-Logistic	24.6
	Period 2 (1982-1999)	Logistic	25.9
	Period 3 (2000-2018)	Extreme Value	23.6
Bozova	Period 1 (1965-1981)	*N/A*	*N/A*
	Period 2 (1982-1999)	*N/A*	*N/A*
	Period 3 (2000-2018)	Lognormal	15.4

As seen in Table 3, there is no clear and distinct probability distribution function for the stations and periods considered. EDI Drought Indexes with 50% probability level obtained for the 3 subgroup or period of each station indicates an increasing drought trend in Şanlıurfa, Akçakale and Ceylanpınarı meteorological stations and their environs. Based on the probabilistic estimates, It might be confidently concluded that Şanlıurfa meteorological station and its environs of "Semi-arid" climate type has been in a tendency to "Arid" climate type. Moreover, Akçakale and Ceylanpınarı meteorological station environs of "Arid" climate type has had a tendency towards "Severe arid" climate type. As shown in Table 3, while Birecik meteorological station and its environs of "Arid" climate type was found to be in a tendency to "Semiarid" climate type, "Semidry" climate type which was developed in the environs of Birecik meteorological station has taken place after the construction of Birecik Dam. Accordingly, while the climate type of Siverek meteorological station environs has had a "Sub-humid" climate type in the first period, i.e. between 1965-1981, the transition from "Sub-humid" climate type to "Humid" climate type has been accelerated or triggered in the second period (between 1982 and 1999), i.e. after the construction of the Atatürk Dam on the Euphrates river. However, it was observed that both the extent and severity of drought episodes has been liable to increase in Siverek station. Based on the overall assessment results, drought prone areas have been disposed to increase in Şanlıurfa, Akçakale, Ceylanpınarı and Siverek meteorological stations and their environs in the long run. Construction of Birecik Dam has hindered drought development to some extent, indicating a positive effect on the local climatic factors by raising the humidity in the region. Due to the lack of yearly data at the Bozova meteorological station in period-1 and period-2, EDI for this location could only be calculated for the period-3. It was concluded that "Semiarid" climate type has been preponderant at the Bozova station and its environs.

Erinç drought index maps with 50% probability level for the periods

After determining the EDI values pursuant to 50% probability at each station for three periods in turn, maps for three different time periods were generated in GIS media, through using by ordinary kriging method, in order to figure out spatio-temporal tendencies of climate types in Şanlıurfa town and its environs. The generated maps by the periods show that climate types conspicuously exhibit spatial dependence. This behavior might be responsible for spatial clustering of meteorological variables over the area (Figure 2).

As seen in the Figure 2, "Arid", "Semi-arid" and "Sub-humid" climate types have been the staple climatic characteristics of Şanlurfa province and its environs.

Those climate types have dominated from south to north, respectively. The arid zone extended into the Syrian border starting from Harran district to Akçakale and Ceylanpınar environs in the period of 1965 and 1981 (Period 1). On the other hand, "Semi-arid" climate type was preponderant effectively in the region, stretching from north of Akçakale and Ceylanpınarı line to Siverek environs where "Sub-humid" climate type appeared onwards.

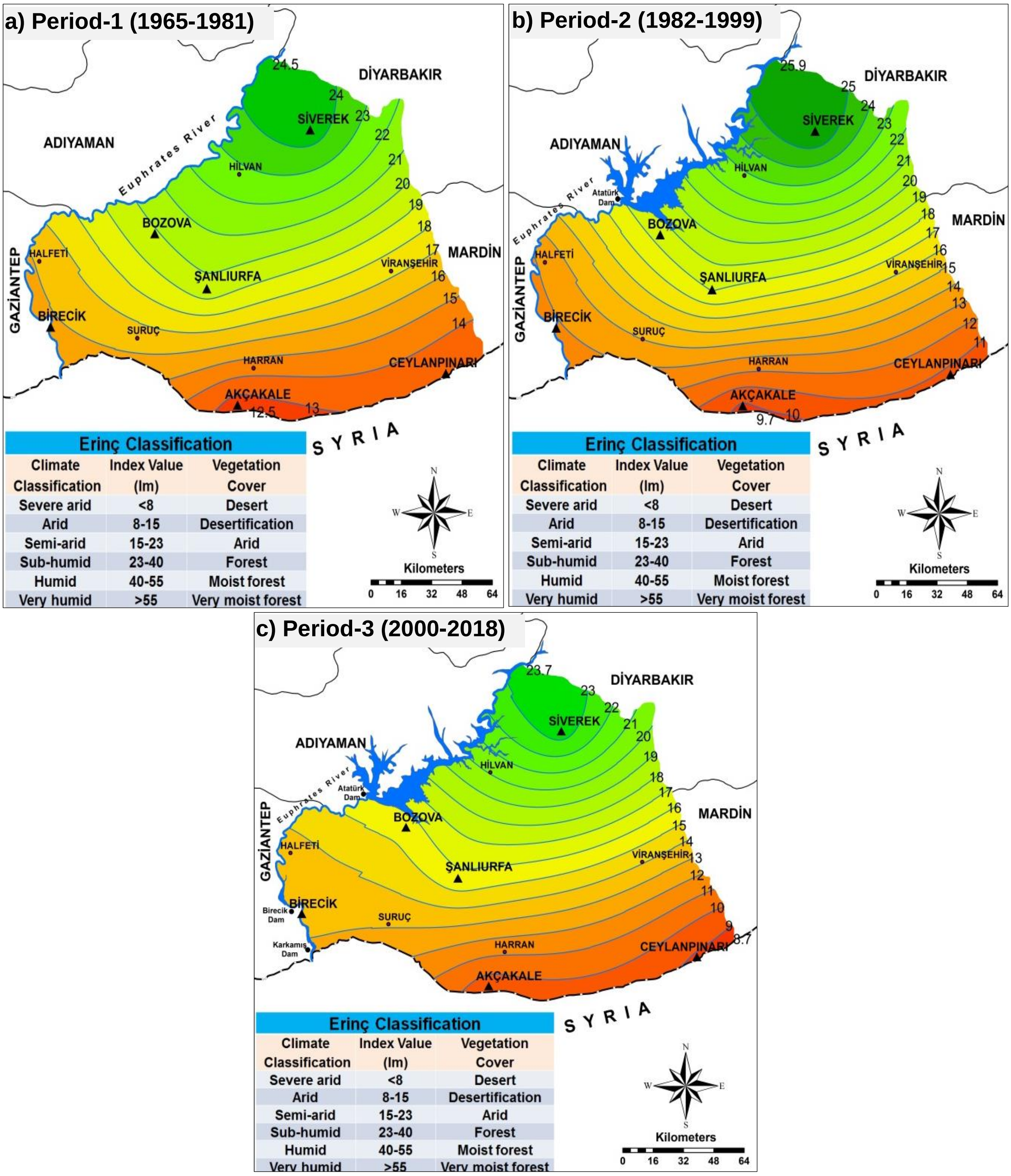

Figure 2. Spatio-temporal tendencies of climate types Şanlıurfa province by the periods considered

In Period-2 (1982-1999), regardless of the fact that the Atatürk Dam was put into operation in 1992, the "Arid" climate type had continued to spread along Halfeti, Birecik, Suruç, Harran, Akçakale and Ceylanpınarı corridor. The "Semi-arid" climate type dominated in the region from the northern of this corridor to Siverek town. On the other hand, "Sub-humid" climate type continued to expand into the direction of Siverek environs starting from the northern part of the upstream of the Atatürk Dam. It was interpreted that the increase of humidity in this period was due to the construction of the Atatürk Dam. Our research findings showed similarities with Tonkaz and Cetin (2007) and were in good agreement with the findings given by Tonkaz et al. (2007).

A number of large dams have been constructed and put into operation in the Period-3 (2000-2018). Although the Atatürk Dam, Karkamış Dam and Birecik Dam were gradually operationalized in 1992, 1999 and 2000, respectively, “Arid” climate type continued inconceivably to spread from the south of the Ataturk Dam upstream, Bozova, Şanlıurfa and Viranşehir corridor. In addition to that, “Semi-arid” climate type continued to stretch away up to Siverek in the north of the corridor established too. It has been observed that “Sub-humid“ climate type influenced a very small area located in the north of the Atatürk Dam, but its influence continued in a small part of Siverek town. As a result, it has been determined that the “Arid” climate characteristic has been spreading out to the northern parts of the study area, starting from the Akçakale boundary line up to the province of Şanlıurfa. Although the Atatürk, the Birecik, and the Karkamış Dams have exerted an influence on mitigating drought expansion in the northwestern parts of the study area, it is unlikely that it would prevent the spread of drought episodes in the future because of global warming and/or climate change phenomena.

CONCLUSIONS

This study was carried out in Şanlıurfa town and its environs –located in the Southeastern Anatolia Project (GAP) area– in order to figure out spatio-temporal tendencies of climate-types. In line with this objective, Erinç Drought Index series were successfully obtained by using long-term annual total precipitation and annual maximum temperature data sets. After this series was divided into three non-overlapping successive parts or periods, i.e. period-1 (1965-1981), period-2 (1982-1999) and period-3 (2000-2018), the best fitting probability distribution models for the EDI series of each period were in turn determined by performing a regular frequency analysis technique. There is not a unique probability function for the data analyzed. Phase one of this study was successfully achieved by means of estimating EDI values of 50% probability level for the three periods of each station. The second phase of the study was completed by generating climate maps over the study area for the three successive periods. The following conclusions might be drawn from research findings:

- ✓ Based on the EDI values of 50% probability level for Birecik and Siverek meteorological stations for the period-1 and period-2, construction of dams have had a positive influence on local climate factors by increasing the humidity in the region.
- ✓ “Arid”, “Semiarid” and “Subhumid“ climate types have dominated in Şanlurfa province and its environs by the periods, stretching from south to the north, respectively, and showed spatio-temporal tendencies in the region.
- ✓ The spatio-temporal variability in “Arid” climate type has gradually continued to spread away from south to north in all three periods.
- ✓ Although construction of the Atatürk, the Birecik, and the Karkamış Dams has resulted in a good influence on mitigating drought expansion in the northwestern parts of the study area, it is unlikely that it would prevent the spread of the future trends in drought episodes because of global warming and or climate change phenomena.
- ✓ It was strongly recommended that spatio-temporal climate change studies be periodically conducted for the whole GAP area.
- ✓ In order to mitigate negative effects of climate change, forestation and forest management practices should be planned and implemented urgently in Şanlıurfa town and its environs.

DECLARATION OF CONFLICTING INTERESTS

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

REFERENCES

Aktaş S, Kalyoncuoğlu ÜY, Anadolu Kılıç NC (2018) Drought analysis using De Martonne method in the Eğirdir Lake basin. Journal of Engineering Sciences and Design, 6(2): 229- 238.

Anonymous (2004) BestFit, Users’s guide @risk risk analysis and simulation add-in for microsoft®excel. Retrieved June 27, 2019, from www. palisade.com/risk/.

Anonymous (2011) MEU, Republic of Turkey climate change strategy 2010-2023. Retrieved June 27, 2019, from https://csb.gov.tr/.

Anonymous (2012) MEU, Republic of Turkey national climate change action plan 2011-2023. Retrieved June 27, 2019, from https://csb.gov.tr/.

Anonymous (2014) IPCC, Climate change 2014 synthesis report summary for policymakers. Retrieved June 27, 2019, from www.ipcc.ch.

Anonymous (2015) AAS, The science of climate change questions and answers. Retrieved June 27, 2019, from www.science.org.au.

Anonymous (2018) UNFCCC, UN climate change annual report. Retrieved June 27, 2019, from https://unfccc.int/sites/default/files/resource/UN-Climate-Change-Annual-Report-2018.pdf

Anonymous (2019a) NASA, Climate change: How do we know?. Retrieved June 27, 2019, from https://climate.nasa.gov/evidence/.

Anonymous (2019b) WMO, WMO statement on the state of the global climate in 2018. Retrieved June 27, 2019 from, https://library.wmo.int/.

Anonymous (2019c) GDM, Surface area of Turkey's provinces and districs. Retrieved June 27, 2019, from www.harita.gov.tr.

Anonymous (2019d) ESRI, Spatial analysis. Retrieved June 27, 2019, from www.esri.com.

Birpınar ME, Tuğaç C (2018) Impacts of climate change on water resources of Turkey. 4th International Conference Water Resources and Wetlands, 5-9 September, Tulcea (Romania). pp. 145-152.

Burgess TM, Webster R (1980) Optimal interpolation and isarithmic mapping of soil properties I, the semivariogram and punctual Kriging. Journal of Soil Science, 31(3):315-331.

Celik MA, Gülersoy AE (2018) Climate classification and drought analysis of Mersin. Celal Bayar University Journal of Social Sciences, 16(1):1-26.

Cetin M (2020) Agricultural Water Use. In: Harmancioglu N., Altinbilek D. (eds) Water Resources of Turkey. World Water Resources, Vol 2. Springer, Cham (First Online: 05 June, 2019).

Cetin M (1996) Point and Areal Estimation of Precipitation by Geostatistical Methods and Stochasically Modelling: Application to Catchments. PhD Thesis, Cukurova University, Institute of Basic and Applied Sciences, Department of Agricultural Structures and Irrigation. Adana, Turkey, 127p (in Turkish with English abstract).

Chow VT, Maidment DR, Mays LW (1988) Applied Hydrology. McGraw-Hill, Inc., Civil Engineering Series, New York, 572p.

Demircan M, Gürkan H, Eskioğlu O, Arabacı H, Coşkun M (2017) Climate change projections for Turkey: Three models and two scenarios. Turkish Journal of Water Science and Management, 1(1):22-43.

Erinç S (1965) An attempt on precipitation efficiency and a new index. Istanbul University Institute Release, Baha Press, Istanbul (in Turkish).

Haider S, Adnan S (2014) Classification and assessment of aridity over Pakistan provinces (1960-2009). International Journal of Environment, 3(4):17-35.

İrvem A, Özbuldu M, Çıplak C (2018) Drought analysis by using stream flow data of the Seyhan Göksu-Himmetli sub-basin. Journal of Agricultural Faculty of Mustafa Kemal University, 23(2):148-157.

Li Y, Yao N, Sahin S, Appels WM (2017) Spatiotemporal variability of four precipitation-based drought indices in Xinjiang, China. Theoretical and Applied Climatology, 129:1017-1034.

Mert BA, Dağ A (2017) Computer program for practical semivariogram modeling and Ordinary Kriging: a case study of porosity distribution in an oil field. Central European Journal of Geosciences,9:663-974.

Mishra AK, Singh VP (2010) A review of drought concepts. Journal of Hydrology, 391: 202-216.

Sen Z (2015) Applied Drought Modeling, Prediction and Mitigation. Elsevier: 97801280 24225, Amsterdam, Netherlands. 484p.

Tabios III GQ, Salas JD (1985) A Comparative analysis of techniques for spatial interpolation of precipitation. Water Resources Bulletin, 21(3):365-380.

Tayanç M, İm U, Doğruel M, Karaca M (2009) Climate change in Turkey for the last half century. Climatic Change, 94:483-502.

Tonkaz T, Cetin M , Tulucu K (2007) The Impact of water resources development projects on water vapor pressure trends in a semi-arid region. Turkey. Climatic Change, 82:195-209.

Tonkaz T, Cetin M (2007) Effects of urbanization and land-use type on monthly extreme temperatures in a developing semi-arid region, Turkey. Journal of Arid Environments, 68: 143–158.

Tonkaz T (2006) Spatio-temporal assessment of historical droughts using SPI with GIS in GAP Region, Turkey. Journal of Applied Sciences, 6(12):2665-2571.

Türkeş M, Akgündüz AS (2011) Assessment of the desertification vulnerability of the Cappadocian district (Central Anatolia, Turkey) based on aridity and climate-process system. International Journal of Human Sciences, 8(1): 1234-1268.

Yılmaz AG, Imteaz MA (2014) Climate change and water resources in Turkey: a review. International Journal of Water, 8(3):299-313.