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Seasonality Determination of Stream Flows For Planning Hydraulic Structures in Kızılırmak Basin

Kızılırmak Havzasında Hidrolik Yapıların Planlanmasında Nehir Akımlarının Mevsimselliğinin Belirlenmesi

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ABSTRACT

The demand for water resources is increasing day by day due to the rapid increase in the world population, drought caused by industrialization, urbanization and global climate change. The efficient use of water resources depends on the correct planning and operation of the water resources systems of the future. The seasonality analysis is to reveal the similarities between the hydrological characteristics of streamflows regionally. In this study; the seasonal similarity of low and high flows throughout the year was determined by using the daily flow data from 5 streamflow gauging stations selected at certain geographical points across the Kızılırmak basin. The similarity of the basins was determined by using the seasonal statistics calculated and the direction of the average occurrence dates for each station. The similarity revealed was also associated with the hydrological similarity between stations and the hydrological characteristics of the basins were found.

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ÖZET

Dünya nüfusunun hızla artması, sanayileşmenin neden olduğu kuraklık, kentleşme ve küresel iklim değişikliği nedeniyle su kaynaklarına olan talep her geçen gün artmaktadır. Su kaynaklarının verimli kullanılması, geleceğin su kaynakları sistemlerinin doğru planlanması ve işletilmesine bağlıdır. Mevsimsellik analizi, bölgesel olarak akışların hidrolojik özellikleri arasındaki benzerlikleri ortaya çıkarmaktır. Bu çalışmada, Kızılırmak havzası boyunca belirli coğrafi noktalarda seçilen 5 adet akarsu akış ölçüm istasyonundan alınan günlük akım verileri kullanılarak yıl boyunca düşük ve yüksek akımların mevsimsel benzerliği belirlenmiştir. Burada, yüksek akımların göz önüne alınmasının en önemli nedeni, bu akımların özelliklerinin sel gibi su kaynaklarının planlanması ve işletilmesinin temel unsurlarını oluşturmasıdır. Havzaların benzerliği, her istasyon için hesaplanan mevsimsel istatistikler ve ortalama oluşum tarihlerinin yönü kullanılarak belirlenmiştir. Ortaya çıkarılan benzerlik, istasyonlar arasındaki hidrolojik benzerlikle de ilişkilendirilmiş ve havzaların hidrolojik özellikleri bulunmuştur.

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1. INTRODUCTION

Water is an essential substance for human life, as well as an energy source. However, these resources have been under the threat of global warming since the mid-1980s. Heavy downpours, especially in recent years, create significant changes in the flows in the river basins. These, in turn, cause flood disasters in rivers to be more frequent and severe today. The efficient use of our water resources depends on the correct planning and operation of the water resources systems of the future [1]. Due to population growth and changing consumption patterns, it is expected that the demand for water will increase and this will lead to water conflicts [2].

In Turkey, the demand for energy is increasing rapidly with the effect of social, economic and technological developments and increasing population. To meet this demand, high quality, reliable, environmentally friendly and economical energy sources are needed. Due to the scarcity of fossil resources in our country, it is necessary to make more use of renewable energy. Hydroelectric energy is preferred because it is a reliable energy source. The reasons for this are that it has the possibility of storage and use when necessary, has a long economic life, is environmentally friendly, has no fuel costs, has a short payback period and has high efficiency. Time series analysis of river flows can provide answers to questions regarding the feasibility and management of a hydraulic structure investment. For example, the maximum amount of water needed for energy production or irrigation can be defined more efficiently for the future. Such operations are carried out by statistical control methods based on temporal data. Thus, the liability of the investor can be determined in advance. Most water resources development projects are designed to be used efficiently for 50-100 years or more. The project development and design of hydraulic structures are generally carried out using the forecasts of flood and/or drought events that may occur in 50 or 100 years with the existing meteorological and hydrological records. [3]. However, trends in climate parameters such as precipitation and temperature are often not taken into account during the design phase of water structure projects. Therefore, projects prepared without considering climatic trends and seasonality of river flows can cause major problems, especially during the operation of the facilities [4].

In terms of flow duration, flows are classified as perennial, intermittent and short-lived flows. A stream network with continuous flow is governed by groundwater flow. Therefore, it depends on the average annual precipitation modified by the watershed features; transient flows, i.e. intermittent or short-lived, occur once or more each year and are responses to seasonal climate and individual precipitation events [5].

One of the hydrological functions of perennial streams is as a perennial snow and regional seasonal link, which progresses in daily life during short intermittent seasons. It depends on what's going on with the events in the air tonight [6].The seasonality of stream flow varies regionally, depending on the timing of maximum precipitation, evapotranspiration and contributions from snow and ice, and air temperature. The delays between precipitation peaks and stream flow vary smoothly, from long delays in high latitudes and mountainous regions to short delays in the warmest sectors [7].

In many applications of hydrology and water resources engineering; flood seasonality information is required in seasonal flow estimations, creek bed flood protection, flood management and water resources infrastructure studies [8]. Flood seasonality is information used during the preparation of all construction projects to be planned for water resources control and assessment. Seasonal forecasts of water availability in a basin are useful to managers and planners involved in a variety of activities such as agriculture, water supply, and reservoir management.

Many research has been done on the subject in the world. In the study called "Global characteristics of stream flow seasonality and variability, monthly stream flow series from 1345 sites around the world" were used for characterizing geographic differences in the seasonality and year-to-year variability of stream flow. As a result of study stream flow seasonality varies regionally, depending on the timing of maximum precipitation, evapotranspiration, and contributions from snow and ice [9]. In the UK, the development of seasonal river flow estimation methods has previously been limited to either a few watersheds. Besides, it included the summer season [10]. Eisner et al. selected eleven representative major river basins to study the effects of climate change on the seasonality of stream flow. The basin set includes Rhine and Tagus in Europe, upper Amazon in South America, upper Mississippi in North America, Lena, Ganges, upper Yellow, and upper Yangtze in Asia, Blue Nile and Niger in Africa, and Darling in Australia. As a result of the research, the predicted fluvial flow seasonality differences between the low-emission route and the high-emission route were small in most basins, except for four basins. The old methods are based on empirical relationships between hydrological indicators and climate indices in previous months [11]. In Brazil, low flow seasonality and its effects on water availability along the river network were studied. The study was performed for 16 streamflow gauging stations in Piranga basin. The results show that the annual Q95 is 31% higher than the Q7.10, whereas the monthly values were statistically equal [12]. According to different study, as a result of the assessment of the contribution of groundwater discharges to rivers using monthly flow statistics and flow seasonality in South Africa, it was found that seasonality has a great effect on groundwater potential [13]. Seasonality index (IS), concentration date (PK) half-flow date (TPO), and seasonality coefficient (GMO) were use in study of determining the seasonality of flow in 25 stations on two major rivers in Poland. I was seen that as the catchment area increased, the seasonality of the Vistula flows became considerably higher than of the Oder, and the differences were the most pronounced in the 1960s and 1970s. [14]. In different study, seasonality and variability of daily flows of 40 stations in Mexico City were evaluated based on hydrology, climate, and geography. Variability tests and PCA method were used. As a result, seasonality and variability of river flows were evaluated in terms of climate-smart environmental flow reference values [15]. Eng et al. identified five distinct seasonality patterns in the zero-flow events in the United States and strong correlation patterns with historical variations in climate [16]. In other study, identification of seasonal streamflow regimes and streamflow drivers for daily and peak flows of 253 streamgages in Alaska was actualized. Basin characteristics and weather station observations were used to support the interpretations of drivers and were explored as explanatory variables of differences in seasonal flow regimes[17]. In the literature, seasonality and similarity analyzes of flows have also been used to analyze the effects of river regimes on animal (like fish) populations. These studies provided a comprehensive understanding of environmental systems [18], [19].

It is important to determine the seasonality of flow data for the future of many water resources engineering projects. The occurrence times of high and low flows determined by seasonality analysis are required for planning such as irrigation, operation, determination of facility capacity, flood and drought analyzes of non-accumulative hydroelectric facilities. While considering the homogeneous basins used in regionalization analyzes, their hydrological similarities are taken into account rather than geographical neighborhood. Flood characteristics and occurrence times are used to determine basin homogeneity [1].

Missing or incomplete data creates problems in field studies. The inadequacy of flow measurements is a major problem in terms of efficient use of water resources. Flow measurements in many river basins in Turkey are not available or insufficient. Flow estimations are made in non-measured basins with regional analysis. In order to solve this problem, there are techniques that allow the attribution of appropriate values instead of missing values. The main purpose of regionalization is to ensure the transfer of flows within the region by dividing the basins into groups with sufficient similarity. In order to complete the missing data, flow assignment (regression, hot / cold deck, multi-disposal) can be made for the missing year among the stations with similar characteristics. It is possible to complete the missing data by using the data of the stations that show homogeneity as a result of similarity and seasonality analysis.

In this study; the seasonality of high and low flows during the year was examined by using the daily flows of 5 streamflow gauging stations located at different points on the Kızılırmak River in the Kızılırmak Basin. The reasons for choosing the Kızılırmak basin in the study are that it is the second largest basin in Turkey, has a precipitation area of approximately 10.49% of the country's surface area, and covers some parts of the Central Anatolia, Black Sea and Eastern Anatolia Regions. Other reasons for the preference of the basin are that various climates are effective in the basin due to its location, there are 15 important dams and many small hydroelectric power plants on the Kızılırmak River, which is the longest river in Turkey, and its tributaries. It is of great importance in terms of the planning and management of water resources in the basin, as there are occurrences of drought and flood events. The effect of the variability of the flow rates for each station on the date of the average was determined with the calculated seasonal statistics. The formation dates and regularity of the flows are indicative of the similarity in the hydrological characteristics of the basins. The regional similarities between the hydrological characteristics of the flows in the Kızılırmak basin were determined with the seasonality analysis, and the manageability of many basins was investigated with a general operating policy. The results were evaluated in the planning and operation of hydraulic structures, flood and drought analyzes as well as estimation of flows at unmeasured points in the basin. The results of the study are important in water resources engineering projects, especially in the operation of hydroelectric power plants.

2. SEASONAL ANALYSIS

The dates and regularities of the flows are indicative of the similarity in the hydrological characteristics of the basins. The seasonal behavior of the flows occurring at the time of their formation also gives the similarity of the physical, geographical and meteorological characteristics of the basins. Basins with this similarity show similar characteristics against flows coming in the same time period [20].

2.1. Seasonal Analysis Using Directive Analysis

If the dates of the flows with certain exceedance probabilities are to be determined, the angular value of these dates in radians can be calculated [21]. If January 1 is the 1st day and December 31 is the 365th day, the angular value of the date of occurrence of the flow;

$$\theta = (JULDATE)_i \cdot \frac{2\pi}{365} \quad (1)$$

Here, θ is the angular value in radians of the date of occurrence of any flow. The flow date can be converted to a vector of unit length and in the θ direction. The x and y coordinates of the unit vector; for N streams are given by Equations (2) and (3).

$$\bar{x} = \frac{1}{N} \sum_{i=1}^{N} cos\,(\theta_i) \quad (2)$$

$$\bar{y} = \frac{1}{N} \sum_{i=1}^{N} sin\,(\theta_i) \quad (3)$$

The average directions of flow dates from these coordinates are calculated as follows;

$\bar{\theta} = arctan\,(\frac{\bar{y}}{\bar{x}})$ (for the 1st and 4th regions of the Cartesian coordinate plane with x>0)

$\bar{\theta} = arctan\left(\frac{\bar{y}}{\bar{x}}\right) + \pi$ (for the 2nd and 3rd region of the Cartesian coordinate plane with x>0)

$$md = \bar{\theta}\frac{365}{2\pi} \quad (4)$$

Here, *md* is the day showing the average dates of the flows. Basins with similar *md* values also show similar behaviors in terms of other hydrological characteristics. Average days depend on the size of the basin and the geographical region.

Considering that a flow series consists of n elements, the variability around the mean value can be calculated by Equation (5).

$$\bar{r} = \sqrt{\bar{x}^2 + \bar{y}^2} \quad (5)$$

Here *r* is a dimensionless measure of the scattering of data around average days. The value of *r* ranges from 0 to 1. If *r* is equal to 1 it is indicated that the flows occur on the same day. For this reason, the flows with *r* values approaching to 1 are formed. For this reason, flows with r values approaching 1 show regularity in terms of their occurrence times. On the other hand, if *r* value converges to 0 it is seen an indication of the irregularity between the days of occurrence of flows. Seasonality application is also used to calculate the difference between basins. A numerical value can be obtained to show the measure of the distribution in the seasonal space of the basins. This value can be calculated with the relationship given by Equation (6).

$$d_1^{ij} = \sqrt{(\bar{x}_i^2 + \bar{x}_i^2)^2 + (\bar{y}_j^2 + \bar{y}_j^2)^2} \quad (6)$$

Here, it shows the "Euclidean" distance between the two basins. The smaller this value, the more similar are the two basin streams compared in terms of their behavior.

2.2. Seasonal Analysis Using Relative Frequencies

The basis of the seasonality research of the flows depends on the clustering of the days of occurrence of the flows according to the calendar months. The selected interval should be 1 month. The regularity of flood regimes decreases in shorter periods. If longer intervals were used, a typical separation was not observed [22].

In this study; The hydroelectric power plants. of the flows were grouped into months and the relative frequencies were calculated for each month. In the method, a year in a circle corresponds to 360 days, and every 1 degree corresponds to 1 day. In this case, the sum of the original frequencies (f_i) (s) will not be equal to the sum of the arranged frequencies (f_i ') (s'). The relationship given in Equation (7) is used to ensure equality.

$$\sum_1^{12} f_i' = \sum_1^{12} f_i' \ (\frac{s}{s'}) \quad (7)$$

The 12 month dependent frequency value indicating flood or rain formation can be used to determine the seasonal value within the year. Moreover, such regime descriptors do not vary for models to be applied to hydrological events [22]. The similarity of two basins (*i* and *j*) are measured in the dataset with the use of calculated 12 regulated frequencies.

$$d_2^{ij} = \sqrt{\sum_{k=1}^{12}(f_k^i - f_k^j)^{\,2}} \quad (8)$$

2.3. Flow Continuity Curve and Specific Flow Continuity Curve

The flow continuity curve shows the probability of occurence of flow in a river at a given percentage of time. The flow continuity curve shows the relationship between the amount and frequency of daily, weekly, monthly flows at a given station. It shows the percentage of time that the given flow is equal to or exceeded during a given time interval. For cases where the percentage of time is greater than or equal to a certain value, the flow is calculated using the flow continuity curve. The flow continuity line is obtained by moving the flow rates to the vertical axis and the time percentages to the horizontal axis [23].

The flow obtained by dividing the flow by the cross-sectional area is the "specific flow". Considering that the sizes of the basins in the study area are different from each other, working with the flow continuity curve obtained by using specific flow rates provides more efficient results in the comparison of basins.

The flow continuity curve shows the probability of finding the flow in a stream at a given percentage of time. Flows on the stream in less than a year show a statistically time-varying process. For this reason, statistical properties such as mean, standard deviation, skewness coefficient are variable over time. Therefore, the probability of daily flows exceeding a certain value depends on the day in the year [24].

3. DATA

Daily low and high flow values of 5 streamflow gauging stations in the Kızılırmak Basin were used in this study. The stations were selected from different regions (sub-basins) and active ones in order to fully represent the basin. The data length of the flow stations are 45 years covering the years 1970-2015. The Kızılırmak Basin covers an area of 82221 km^2. The circumference of the basin is 3546 km. The length of the basin is 293 km. Due to the wideness of the basin, there are differences in climate types, as well as evaporation values within the basin. The average temperature of the Kızılırmak Basin was calculated as 10.5 °C. The average temperature in February throughout the basin falls below 0°C. The hottest months are July and August, with average temperatures above 20°C. Due to the wideness of the basin, there are differences in climate types, as well as evaporation values within the basin. The highest evaporation values have been seen in the part of the Kızılırmak Basin bordering the Konya Closed Basin. Evaporation values are at the lowest level in the north of the basin. While evaporation is low in the regions where the Black Sea climate is dominant, evaporation is high in the regions where the continental climate is dominant [25]. The locations of the stations used in the basin are shown in Figure 1.

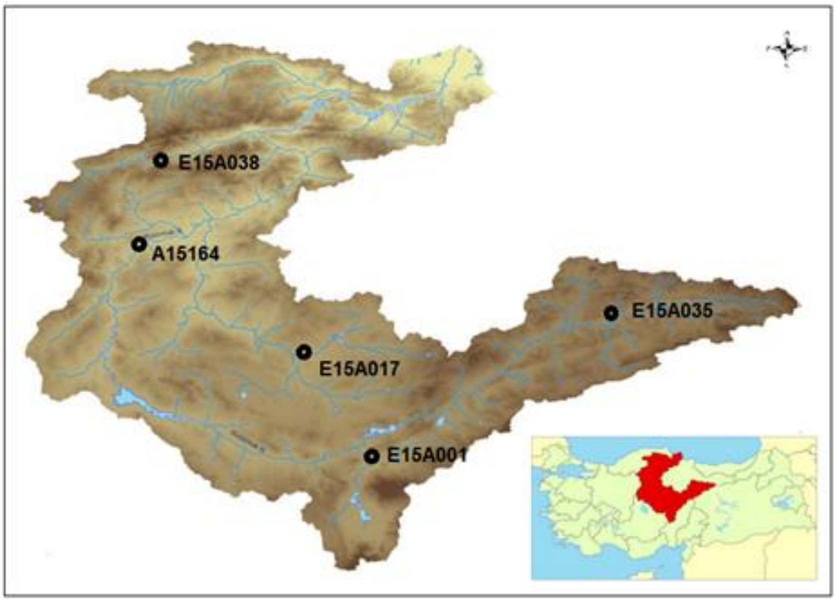

Figure 1. Kızılırmak Basin and streamflow gauging stations.

The Physical properties and statistical data of the stations are shown in Table 1.

Table 1. Physical characteristics and statistical data of stations.

Station No	Station Name	Precipitation Area (m^2)	Altitude (m)	Min. Flow (m^3/s)	Max. Flow (m^3/s)
E15A001	Kızılırmak -Yamula	15581.60	995	0.56	1089.00
E15A017	Karanlık – Şefaatli	8592.40	895	0.41	164.00
E15A035	Kızılırmak – Söğütlühan	6606.50	1243	1.48	589.00
E15A038	Devres – Çeltikçibaşı	1962.00	775	0.12	558.00
D15A164	Kızılırmak – Sofular	33422	548	2.31	277.00

Table 1 shows that E15A001 station has the largest precipitation area and maximum flow. The difference between the minimum and maximum flow is also quite high for the same station. This situation is similar for the other stations. These differences emphasize the importance of seasonality in the design studies of hydraulic structures to be established in these regions.

4. RESULTS

In the study, firstly, a specific flow continuity curve was obtained for each station in order to check that the catchment area has no effect on seasonality (Figure 2a-e). The flow continuity curve was obtained by calculating the percentages of time the flow was greater than or equal to a certain value. In figures, the x-axis represents the percent of time (time percents where the flow was greater than or equal to a certain value), and the y-axis represents the specific flow. Seasonality has been applied over the specific flow continuity curve, on certain percentages of exceedance and the sections above which are important parts for the planning and operation of hydraulic structures.

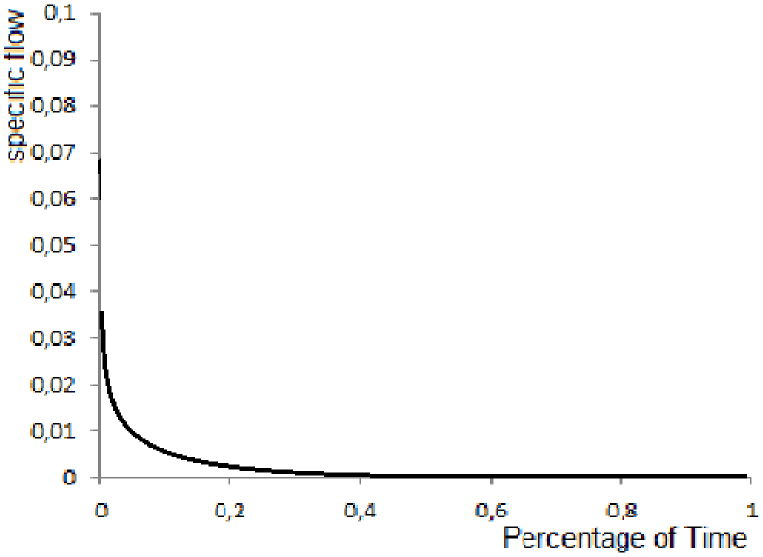

Figure 2a. The specific flow continuity curve of E15A001 station.

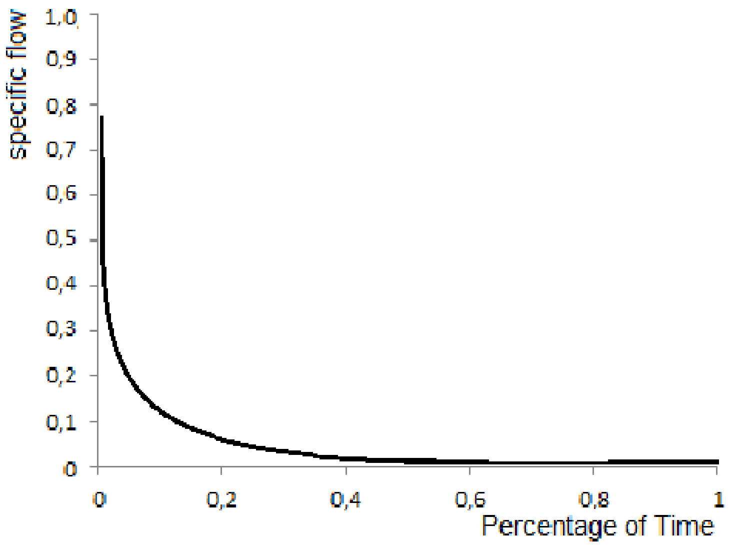

Figure 2b. The specific flow continuity curve of E15A017 station.

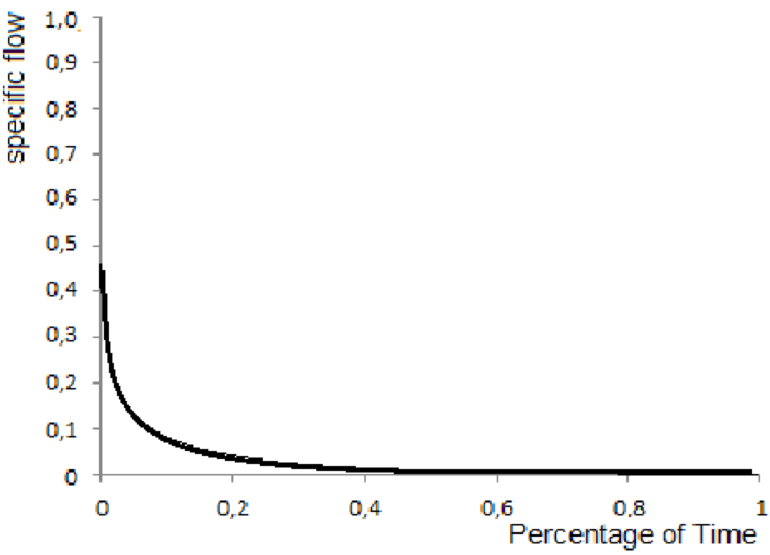

Figure 2c. The specific flow continuity curve of E15A035 station.

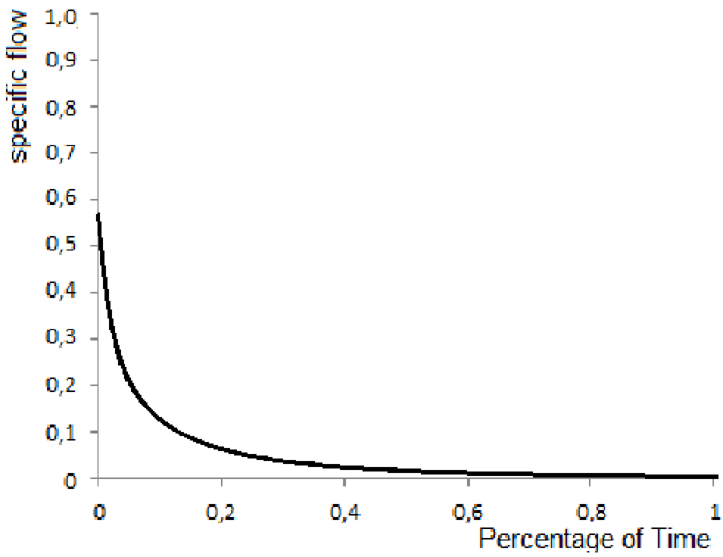

Figure 2d. The specific flow continuity curve of E15A038 station.

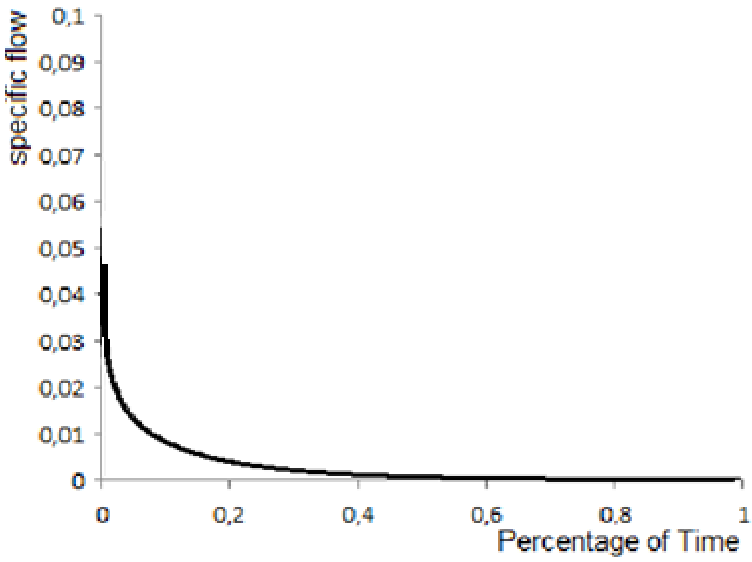

Figure 2e. The specific flow continuity curve of D15A164 station.

Flow values above the 5%, 25%, 50%, 75%, 95% exceedance probabilities and the flow values below the 95% exceedance probability were determined by applying the specific flow continuity curves method. Flow rates above the 5% probability of exceedance are important in the examination of high flows, while the flow rates below the 95% probability of exceedance are important in the examination of low flows. In the seasonality analysis, the analyzes made according to 6 different percentages were beneficial in terms of comparison. Determining the dates of these flow rates is important in terms of observing the distribution of the flows throughout the year. The seasonality indices of the flows corresponding to certain percentages of exceedance from the flow continuity curves are calculated with (1-6) given in the methodology (Table 2).

In Table 2, x and y values show the coordinates of the days of the flows in radians on the cartesian plane. These coordinates are; If the unit placed in the center of the cartesian plane is placed on the circle. The seasonality of the flows is determined by looking at the region where the days of the flows coincide on the circle.

The seasonal area diagram is formed with the unit circle placed on the center of the Cartesian coordinate plane (Fig. 3). In this circle, each degree corresponds to a day. 4 regions of the Cartesian plane are arranged to represent approximately 4 seasons, with the first 3 months of the year being the spring season.

All percentages above the 5%, 25%, 50%, 75%, 95% probability of exceeding the flow rate continuity curve obtained from all stations and below the 95% probability of exceedance on a single plane were shown in Figure 4. The seasonality behavior of flows with certain exceedance probabilities can be examined to a large extent, with this whole demonstration.

Table 2. Seasonality indices of flows at stations.

Station	Probability of exceeding	$\bar{x}$	$\bar{y}$	θ	*Md*	R
E15A001	5%	-0.24004	0.776571	2.283179786	116.748	0.688512
	25%	-0.31321	0.705134	2.348332524	120.056	0.550265
	50%	-0.01997	0.554742	1.90702823	282.333	0.164253
	75%	0.10320	0.445833	1.309931796	666.221	0.099587
	95%	0.03001	0.351723	1.101937195	560.557	0.045423
	>95%	-0.34831	-0.39655	2.256974203	206.389	0.836588
E15A017	5%	-0.42331	-0.70141	4.788072574	243.998	0.647402
	25%	-0.22378	0.761518	2.203288486	112.688	0.582521
	50%	-0.16497	0.701125	2.133846231	109.603	0.487800
	75%	0.108234	0.565483	1.549675091	788.014	0.201104
	95%	0.166174	0.444985	1.057358460	537.910	0.298722
	>95%	-0.45299	-0.26587	3.269874123	199.568	0.898532
E15A035	5%	0.089084	0.350506	1.061047952	539.785	0.083584
	25%	-0.72354	-0.67225	4.722752963	240.685	0.721781
	50%	-0.45687	0.790409	2.130832068	109.007	0.777727
	75%	-0.19267	0.709968	2.093189471	107.094	0.601076
	95%	0.101356	0.556233	1.552260091	789.327	0.281189
	>95%	0.046264	0.045623	0.589230498	056.156	0.025697
E15A038	5%	0.273922	0.436395	0.872900522	505.165	0.192079
	25%	0.053250	0.348047	0.812976537	434.082	0.094819
	50%	-.711120	-0.63027	4.539111912	231.351	0.741213
	75%	-0.48405	0.748673	2.158028980	123.089	0.672737
	95%	-0.51628	0.671497	2.597543974	128.765	0.638705
	>95%	-0.52033	-0.74396	2.102256891	301.444	0.889821
D15A164	5%	-0.09898	0.495627	1.854406425	105.124	0.217913
	25%	0.159840	0.447894	1.366617696	695.018	0.199771
	50%	0.065897	0.351706	1.128038376	573.817	0.064587
	75%	-0.72021	-0.69998	3.913086989	245.269	0.709413
	95%	0.568942	0.757164	2.497497377	122.554	0.787887
	>95%	-0.02018	-0.048458	0.789267791	037.456	0.029874

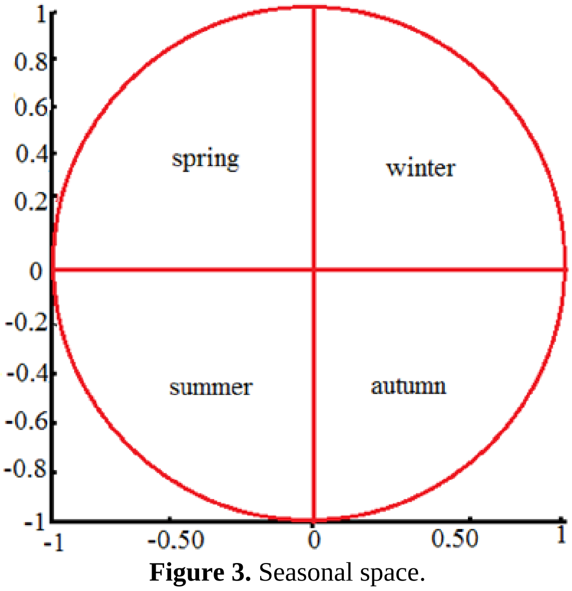

Figure 3. Seasonal space.

The "*r*" value calculated with the (7) represents the proximity of the dates of the flows to the center or the edge on the seasonality graphs. *r* ranges from 0 to 1. If the *r* is equal to 1, it shows that the flows come within the same days. For this reason, flows with *r* approaching 1 show regularity in terms of their occurrence times. The fact that the flows are close to the center in the seasonality flow plane means that the *r* is close to 0. This is an indication of the irregularity between the days of occurrence of the flows. *r* is also a measure of the radii of the seasonality clusters of the dates of the flows distributed on the unit circle drawn on the seasonality space. The dates of flows with a probability of exceeding 95% are closest to the center of the unit circle. The dates of flows with a probability of exceedance of more than 5% are located the farthest from the centre (Figure 4). The probability of exceedance is above 5% and there is regularity of flows in the remaining region of 95%. Flow rates with a probability of exceeding 5% from these values from the flow continuity curve indicate high flows in stations. Flows with a probability of exceeding below 95% indicate low flows. These flows occur in a very small part of the time. For this reason, the regularity and seasonality of these flows within themselves represent the seasonality of the regions within the basin.

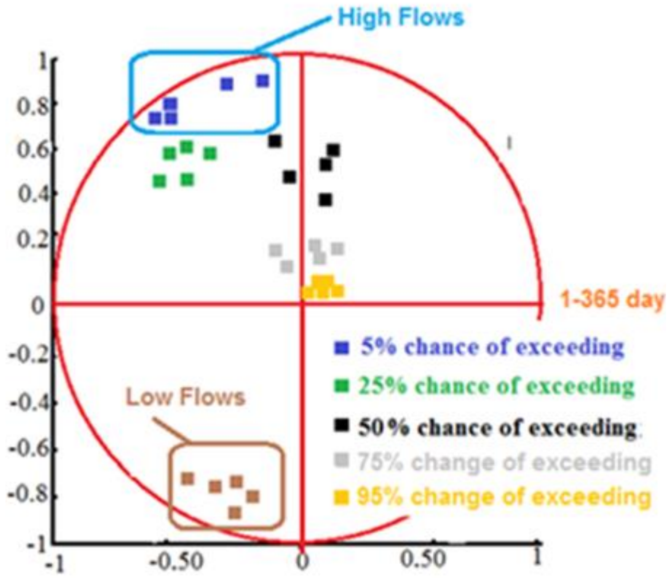

Figure 4. Seasonality Graph Calculated for Flows at Stations.

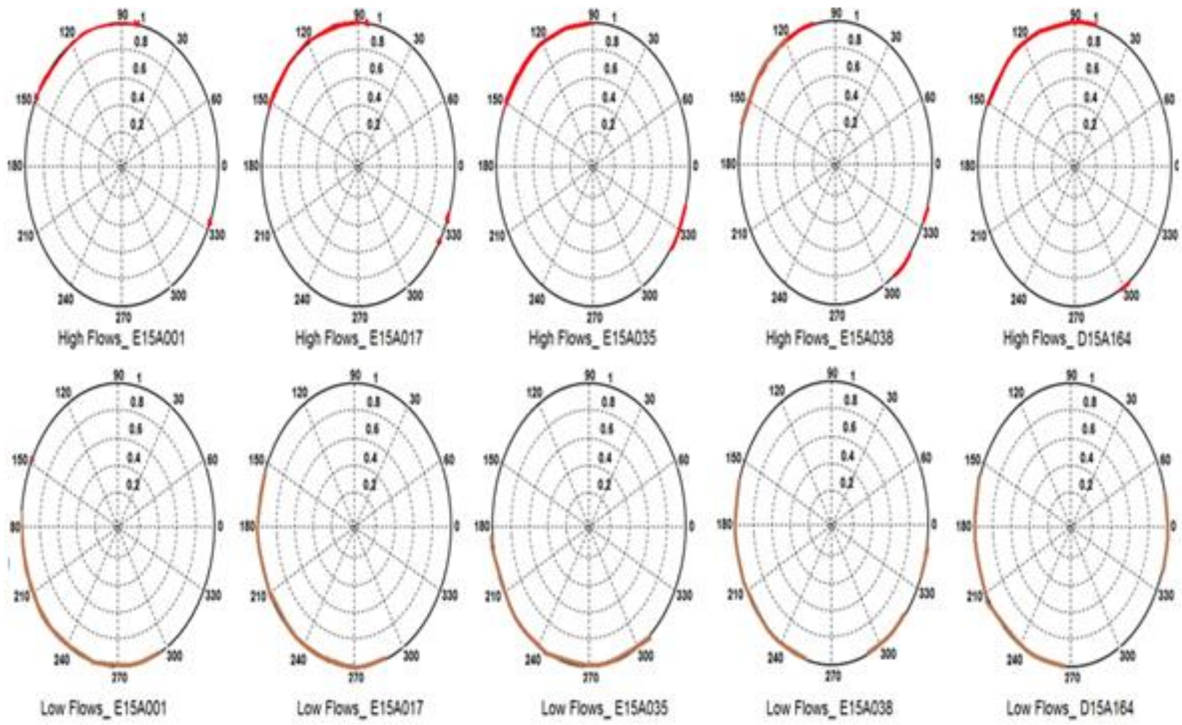

Figure 5. Seasonal days graphs of stations for high and low flows.

According to the results from Figure 5: (a) high flows started in February and continued until the end of April. (b) The small cluster observed around 300-330 degrees is indicative of the autumn rains starting from the end of October. (c) lowest flows are clustered in July-August. This is because there is no precipitation on the river basin and evaporation is at its highest in these months. Figure 5 shows that the river basins show similar seasonality to each other and the seasonality behavior of the flows in the region themselves.

d_1 "Euclidean distance" can also be used for determining the hydrological similarities of the river basins. These values calculated with (8) are given in Table 3.

The Euclidean distance between the basins, symbolized d_1, in Table 3, is an indicator of basin similarity. There is an inverse correlation between d_1 and basin similarity. As d_1 gets smaller, the similarity of the basins increases. The reason why d_1 values are at least 75% and 95%, the basins of all stations are very similar to each other.

The cross-comparison of the similarity of the basins with each other was shown in Table 4. For river basin similarity, homogeneity was symbolized H and NH was used for inhomogeneity.

Table 4 evaluation; for the 5% probability of exceedance and the flows remaining above, (a) station E15A001 was similar to stations E15A017, E15A037, E15A038 and D15A164, (b) Station E15A017 gave homogeneity characteristics with stations E15A001 and E15A018, (c) E15A035, E15A001 and E15A038 were also similar

Table 3. Euclidean distances (d_1) between stations.

	Euclidean Distance	E15A001	E15A017	E15A035	E15A038	D15A164
E15A001	5%	0				
	25%	0				
	50%	0				
	75%	0				
	95%	0				
E15A017	5%	0.093	0			
	25%	0.150	0			
	50%	0.119	0			
	75%	0.069	0			
	95%	0.006	0			
E15A035	5%	0.123	0.235	0		
	25%	0.179	0.325	0		
	50%	0.137	0.236	0		
	75%	0.075	0.121	0		
	95%	0.010	0.006	0		
E15A038	5%	0.101	0.017	0.222	0	
	25%	0.119	0.043	0.288	0	
	50%	0.069	0.050	0.193	0	
	75%	0.012	0.066	0.088	0	
	95%	0.001	0.006	0.011	0	
D15A164	5%	0.083	0.162	0.072	0.165	0
	25%	0.156	0.299	0.029	0.261	0
	50%	0.145	0.249	0.019	0.204	0
	75%	0.067	0.122	0.018	0.079	0
	95%	0.002	0.003	0.008	0.002	0

Table 4. Basin Homogeneity Between Stations.

	Basin Similarity	E15A001	E15A017	E15A035	E15A038	D15A164
E15A001	5%					
	25%					
	50%					
	75%					
	95%					
	>95%					
E15A017	5%	H				
	25%	NH				
	50%	NH				
	75%	H				
	95%	H				
	>95%	NH				
E15A035	5%	H	NH			
	25%	NH	NH			
	50%	NH	NH			
	75%	H	NH			
	95%	H	H			
	>95%	NH	H			
E15A038	5%	H	H	H		
	25%	NH	H	H		
	50%	H	H	H		
	75%	H	H	H		
	95%	H	H	H		
	>95%	H	H	H		
D15A164	5%	H	NH	H	NH	
	25%	NH	NH	H	NH	
	50%	H	NH	H	NH	
	75%	H	H	H	NH	
	95%	H	H	H	H	
	>95%	H	H	H	H	

each other, (d) E15A038 was similar to E15A001, E15A017 and E15A035, (e) D15A164 was similar to E15A001 and E15A038.

For flows with a 95% probability of exceeding and below (low flows): (a) E15A001 is similar to E15A038 and D15A164, (b) E15A017 is similar to E15A038 and D15A164, (c) E15A035 Station numbered shows homogeneity with E15A017, E15A038 and D15A164, (d) Station E15A038 showed homogeneity with all stations, (e) Finally, D15A164 showed similarity with all stations.

5. CONCLUSION

The operational policies of the hydraulic structures planned to be established in the region can be realized more easily by determining the occurrence times of high and low flows with seasonality analysis. The strong seasonal behavior of high flows is very important for flood analysis and desing of hydraulic construction projects. The strong seasonality of low flows also indicates the dry season in the basin. The seasonality analysis also gives an idea about the similarity between the hydrological characteristics of the basin.

Flood protection can be provided with a common policy for basins with similar seasonality. The project flow rate selected for a hydraulic structure planned to be established in the region can also be selected for similar basins. In addition, precautions can be taken for the expected drought in the region by looking at the similarities between 95% and below. Basin similarity is very important in terms of completing the missing measurements as well as its importance for water resources enterprises. Similar river basins show similar hydrological behavior. In this respect, similar measured basin data can be used to complement flow data in non-measured basins.

In this study, 45 years of daily low and high flow data of 5 river measurement stations in the Kızılırmak Basin were used for seasonality analysis. Seasonal analysis was performed for low and high flows for the probability of exceeding 5%, 25%, 50%, 75%, 95% and 95% from the flow continuity curves obtained separately for the stations. Similarities between stations were determined by two different methods. Flow continuity curve was used for each station (Fig.2a-e). It was accepted that the drainage areas of the basins have no effect on the formation dates of the flows. Therefore, the specific flow continuity curve was used by dimensionless flow continuity curves. According to the results of the analysis, high flows are located in the region between the 50th day (20 February) and the 120th day (April 30) (Fig.4). This situation can be interpreted as the melting of february heavy snowfalls in the spring. Snow melts occurred earlier at stations located at lower elevations. The regions where the stations are located are very close to each other for high flows with a probability of exceeding 5%, showed seasonal characteristics. In addition, observed at some stations autumn precipitation also occurred in October-November in the same period. The low flows, which were below the 95% probability of being exceeded, were concentrated in the summer period, which includes July (182th day) and August (232th day). The time intervals in which high and low flows occur in the basins of our country are not very different from each other. For the purpose of comparison with the Kızılırmak basin, for the neighboring Konya basin, the high flow time interval was found as 15 March-30 May, and the low flow time interval was 30 June-1 September (Fig. 5). Although the flow formation intervals in both basins are the same seasonally, there are day differences in the dates. The mentioned day differences are very important especially in the project calculations and operations of hydroelectric power plants.

Euclidean distance were used for determining the hydrological similarities of the river basins. All stations were very similar to each other (Table 3). According to results of the cross-comparison of the similarity analyses of the basins, for the 5% probability of exceedance, station basins showed similarity. For flows with a 95% probability of exceeding and below (low flows), It was observed that the hydrological behavior of stations during the drought period is compatible with the basin (Table 5).

As a result of seasonal analyzes of 5 river flows, it was concluded that there are regional similarities between the hydrological characteristics of river flows in the Kızılırmak basin. This result shows that Kızılırmak basin can be managed with a general operating policy. At the same time, with the positive results of the similarity and seasonality characteristics on the basis of the basin, it can be also possible to complete the missing data in the streamflow gauging stations in the Kızılırmak basin. The basin streamflow gauging stations with complete data in those years can be used for the completion of missing data on the streamflow gauging stations located within Kızılırmak basin. This situation is also very important in terms of the data used in hydraulic construction projects to be built in places where there is not enough data in the basin. In particular, the determination by seasonality analysis will be of great benefit in the efficient and effective planning and operation of hydraulic structures to be built in the basin. Considering that flow measurements are insufficient in Turkey, this method will yield useful results for effective and smart business policies and management of water resources. The occurrence days of the flows occurring at the stations used in the study occur independently of the precipitation area and elevation. This situation shows that the flow continuity curve to be obtained while determining the water potential of hydraulic structures should be independent from the area and obtained with specific flow rates. These curves can be used in the planning of the structures to be built in the places where the streamflow gauging stations are located and in the selection of the project flow rates.In addition, determining the days when high flows occur with seasonal analysis will be of great benefit in the effective and efficient planning and operation of hydroelectric power plants. As a result of the analyzes, the determination of the days when the maximum flows occur is important for the operation of hydraulic structures (such as reservoir overflow).In addition, determining the days when the maximum flows occur will be useful in taking precautions against a possible flood and in the design of the structures. The study will contribute greatly to the prevention of floods and the operation of small hydroelectric power plants, which are numerous in the region, in order to support economic and cultural development in the Kızılırmak basin.

Statement of Conflict of Interest:

Author has declared no conflict of interest.

Author's Contributions:

The contribution of the authors is equal.

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