DETERMINATION OF RUNOFF COEFFICIENT OF BASINS BY USING GEOGRAPHIC INFORMATION SYSTEMS

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ABSTRACT

DETERMINATION OF RUNOFF COEFFICIENT OF BASINS BY USING GEOGRAPHIC INFORMATION SYSTEMS

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Turkey has very different geomorphologic, hydrologic and climatic conditions, so the runoff coefficient should be different from one basin to another. But only one constant value, which is 0.37, is being used for all the basins in Turkey. In this thesis, monthly, seasonal and annual runoff coefficients of 48 sub-basins in western and southern part of Anatolia are determined by using synchronous and average rainfall, runoff data of 26 year record period. Their temporal and spatial distributions are investigated. The relationship between the basin parameters and the runoff coefficient are also examined. Some of the basins have unrealistic large runoff coefficients, therefore excluded from the analyses.

The basin boundaries and parameters are determined by using Geograhic Information System (GIS), and areal average precipitations are found by a program written in visual basic language that uses ArcObjects. The Box-Cox transformed data are used in regression analysis. There are a number of dams in the region, which affect the natural flow. Such streams are found and their sub-basins are not used in the analyses. The results revealed that there is not a strong the relationship between the basin parameters and annual and seasonal runoff coefficients for the whole region, but there are significant relations between them for some basins.

Key words: Runoff Coefficient, Basin Parameters, Geographic Information System (GIS), Box-Cox Transformation, Regression Analysis.

ÖZ

HAVZALARIN AKIŞ KATSAYILARININ COĞRAFİ BİLGİ SİSTEMLERİ YARDIMIYLA BULUNMASI

Acınan, Sezen
Y. Lisans, Jeodezi ve Coğrafi Bilgi Teknolojileri
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Türkiye jeolojik, hidrolojik ve iklimsel açıdan çok farklı koşullara sahiptir. Bu nedenle akış katsayıları havzadan havzaya değişim göstermelidir. Fakat Türkiye'nin tüm havzalarındaki akış katsayıları için 0.37 olan bir değer kullanılmaktadır. Bu tezde, Batı ve Güney Anadolu'daki 48 alt havzanın aylık, mevsimlik ve yıllık akış katsayıları eş zamanlı ve 26 yıl ortalaması olan akım ve yağış verileri kullanılarak bulunmuştur. Bunların zamansal ve konumsal dağılımları incelenir ve havza parametreleriyle aralarındaki ilişkiler araştırılmıştır. Bazı havzaların akış katsayıları gerçeğe aykırı olarak büyük olduğundan bu havzalar analizlerden çıkarılmıştır.

Havza sınırları ve parametreleri Coğrafi Bilgi Sistemleri (CBS) yardımıyla çıkartılmış ve havzaların alansal ortalama yağışları ArcObject içinde visual basic programlama dili kullanarak yazılan bir program yardımıyla bulunmuştur. Box-Cox ile dönüştürülmüş veriler regresyon analizlerinde kullanılmıştır. Bölgede doğal akımı etkileyen çok sayıda baraj vardır. Üzerinde barajların olduğu akarsular bulunup, havzaları analizlere katılmamıştır. Sonuçlar, tüm çalışma alanında yıllık ve mevsimlik akış katsayıları ile havza parametreleri arasında çok güçlü bir ilişkinin bulunmadığını, fakat bazı havzalarda ise bu ilişkinin önemli olduğunu göstermektedir.

Anahtar Kelimeler: Akış Katsayısı, Havza Parametreleri, Cografi Bilgi Sistemleri (CBS), Box-Cox Dönüşümü, Regresyon Analizi.

To My Family

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CHAPTER 1

INTRODUCTION

1.1 Importance of the Study

Water is the most important natural resource for all the living creatures. It is necessary for human beings, economic development, hydroelectric power production, etc., and vital also for ecology of the world.

Water related problems are becoming more important with time because of the fact that while water resources stay the same on the earth, the population of the world and contamination of the water are increasing. This situation causes the global water crisis. Thus, increasing demand on water affects the increasing arguments on economical, environmental and also political issues.

When rain falls onto the earth, it starts moving according to the law of gravity. It is moving within and above the earth in hydrologic cycle. "Basins are areas divided by natural hydrological boundaries and used to manage water resources and develop solutions to environmental problems. These areas include assemblages of natural resources that rely on the type and quantity of water present within the basin" (Reimold, 1998). Basin has an important role in converting precipitation into runoff and its characteristics should be clearly understood. It is a dynamic and very complex system, which has mainly two types of characteristics.

a) Geomorphologic characteristics of the basin, such as area, shape, slope, etc.
b) Hydrologic characteristics such as stream shape, infiltration capacity, soil conditions, vegetal cover, land use, etc.

A part of the rainfall, which falls on a basin, is observed as the runoff at the outlet depending on the characteristics mentioned above. There is also a close relationship between geomorphologic and hydrological characteristics of a basin.

The proportion of the runoff depth to precipitation depth in a certain time interval is expressed as runoff coefficient. It is a depicter of how much rainfall becomes runoff in catchments and also an important parameter for designing hydraulic structures. It gives information about surface water potential of the basins. Knowing runoff coefficients of basins can help us while dealing with water related problems. The hydraulic structures, which are built for water storage, irrigation and flood protection purposes, can be built properly by knowing runoff coefficient.

People are concerned considerably with the control of water since hundreds years. It requires understanding the water behaviors. Having a flood or drought, that is bigger than estimated, can cause so much more damage in both economical and social perspective. If a place, which is suitable for obtaining hydro electrical power, can be found with better estimation of runoff coefficient, this would contribute to the economy of country when the produced energy amount is considered. In addition, obtaining energy from water is important, because it is renewable and does not pollute the environment. Because of these reasons, it is very important to assess the runoff coefficient accurately and to know which basin parameter(s) is/are significant and effective for explaining runoff coefficient.

GIS gives many useful tools for delineating stream network, and obtaining the boundary of basin. It has also facilities for determining the basin parameters. GIS tools provide many operations between different kinds of spatial data for extracting necessary information. The analyses can be done in shorter times with GIS tools, and more accurate results are obtained from the analyses.

1.2 Aim and Scope of the Study

Turkey has very different geomorphologic, hydrologic and climatic conditions in different regions; therefore runoff coefficient is expected to have different values from one basin to another. But only one constant value, which is 0.37, is being used for all basins in Turkey. In this thesis a study is conducted in this subject.

One aim of the study is to determine runoff coefficients in a certain region (possibly large) of Turkey, in different basins and sub-basins of the region, and for different time intervals, from month to year, using GIS tools. Then the temporal and the spatial distributions of these runoff coefficients can be investigated and compared with the constant value accepted for Turkey.

The second aim is to study the relationship between the basin parameters and the runoff coefficient. If there is a relationship, then runoff coefficient can be expressed in terms of the parameters, which are found to be important. It is also important to find out whether this relationship is changing in time or space or both. Basin parameters do not change with time, at least not from one month to the other, but they change from one basin to the other, then the question "is there an explainable relationship between these parameters and the runoff coefficient?" becomes important. This study will try to find out the answers to these questions.

"Computerized data visualization and analysis tools, especially GIS technologies, constitute an important part of today's water resources development and management studies. In order to obtain satisfactory results from such tools, accurate and comprehensive hydrography datasets are needed that include both spatial and hydrologic information on surface water resources and watersheds" (Girgin, 2003). To find digital base maps and hydro-meteorological data are a big problem in hydrologic studies, therefore the maps and data obtained and used for previous studies in GGIT Department of METU are used for new studies by some additions. This way is followed in this study also, and a region from west Anatolia is chosen for the study.

After collecting necessary data, runoff coefficients are determined in western and southern part of Anatolia including 48 sub-basins from Susurluk, Aegean, Gediz, Afyon Closed, West Mediterranean, Antalya, Büyük and Küçük Menderes Basins. Average of synchronous long years data, which were measured at stream gauging stations (SGS) and precipitation observation stations (POS), are used for this purpose. Runoff coefficients are calculated automatically with a program written in ArcObjects and visual basic programming language. Then the temporal and the spatial distributions of these runoff coefficients are examined and compared with the constant value used for whole Turkey.

Next, the temporal and spatial relations are investigated between the runoff coefficients and basin parameters. For this purpose, parameters of 48 sub-basins in the study area are determined by GIS tools. Then, the correlations between the basin parameters themselves are determined. The regression analyses are made by taking into consideration the correlations between the basin parameters. The parameters, which do not have high correlation between them, are used in the analyses so as not to cause any bias in the results. Significant parameter(s) and its/their effective proportion for estimating annual, seasonal, and monthly runoff coefficients of basins are investigated by stepwise regression analyses for the whole study area. The analyses are also done for each basin and among the sub-basins of each basin. The results of the regression analyses reveal information about whether the runoff coefficient can be found accurately by using basin parameters.

For this purpose, first flow directions and accumulation grids of the study area are formed by using digital elevation model (DEM), which gives elevation values in a grid form to express the surface topography. Then, they are used to form stream network definition of study area. Stream gauging stations are taken as outlet points of the basins or sub-basins and their corresponding basin boundaries are determined by using ArcHydro extension of ArcGIS software. The datasets of basin parameters for all basins in the study area, include the basin area (A), perimeter (P), the total river length (TRL), the main channel length (MCL), the basin length (Lh), the basin width (Wh), the main channel slope (MCS), the stream order (SO), the total number of branches (TNB), the basin shape indices (SI1, SI2), the Gravelius index (Kc), the drainage density (Dd), the drainage frequency (Df), the mean basin slope (S), the bifurcation ratio (Rb), which are also determined by using GIS tools.

CHAPTER 2

LITERATURE REVIEW

Runoff is normally expressed as flow volume per unit time. Another runoff expression is the depth equivalent over a drainage basin such as millimeters per day, month or year. It is a particularly useful unit for comparing with precipitation, since precipitation is expressed in depth also. Runoff depth is calculated by dividing the runoff volume for a certain time to the catchment area. For example, 1 millimeter runoff depth is equal to 1000 cubic meter of runoff volume per 1 square kilometer of basin area.

The proportion of the runoff depth to precipitation depth in any certain time interval is expressed as runoff coefficient. It is a dimensionless unit. According to Bayazıt (1995) the runoff coefficient values generally change between 0.05 and 0.50. If it is a proportion of monthly average runoff depth to total monthly precipitation depth, it is called as monthly runoff coefficient. Seasonal runoff coefficient (such as spring or summer runoff coefficient) is calculated as the proportion of the seasonal runoff depth to seasonal precipitation depth. The annual runoff coefficient is the ratio between the annual average runoff depth and the total annual precipitation depth. The runoff coefficient for an event is defined as the portion of the rainfall that becomes direct runoff during the event. The concept of this term dates back to the beginning of the 20^{th} century (e.g. Sherman, 1932). It is still widely used in the engineering design works for hydraulic structures.

Some authors proposed a dependence of runoff ratio on the percentage of impermeable catchment area (e.g. Schaake et al., 1967; Boughton, 1987). Hebson and Wood (1982) assumed a constant runoff coefficient in their study, interpreted as the percentage of contributing area to runoff generation.

Savenije (1996) stated that the runoff coefficient is the key to moisture recycling. It is a good indicator of the importance of the recycling of moisture and for monitoring the change over time of recycling of the moisture in a basin. If there is an increase of the runoff coefficient over time, it is a good indicator of land degradation.

There are two known ways of analyzing the percent contribution of rainfall to streamflow. The first approach is the event scale analysis of runoff and rainfall records. The second approach is tracing the soil moisture conditions of the catchments in a continuous way (Merz et al., 2006).

Moisture recycling by evapotranspiration from vegetation is the most important mechanism sustaining rainfall on catchment in semiarid areas. It is also the most important mechanism sustaining river flow. Land use and rainfall are closely related in semiarid zones. In the Sahel in Africa, more than 90% of the moisture is recycled. It means that more than 90% of the rainfall has been evaporated in the Sahel area (Savenije, 1995). Consequently, there is an important feedback mechanism between the land use and climate, which has immediate implications for natural resources management.

If catchments have low runoff coefficients, each moisture particle is reused a number of times in these catchments. Deforestation, agricultural development, urbanization, drainage or whatever increases the runoff from the catchments, decreases the capacity of the evapotranspiration in the catchments. Hence, there exists a decrease in the rainfall (Savenije, 1996).

Rainfall has been claimed an exogenous factor by many hydrologists. They thought that it is highly influenced by human interference. The total amount of advected moisture may be exogenous, but the number of times that the moisture is recycled in a catchment, depends on the land use. The most important source of rainfall is the moisture recycling, especially in semiarid and arid areas (Savenije, 1996).

There is a misconception that a high runoff coefficient is good in terms of water resources development. There exists an argument about forests that consume water and reduce runoff from a catchment. This argument is at least partly wrong. The total amount of advected moisture from the ocean does not change by afforestation or by deforestation. So, the total runoff remains the same. Although the runoff coefficient may increase, the rainfall decreases and the total runoff remains the same. The argument is partly right. Because afforestation on the mountain ranges bordering the catchment may increase the moisture content along the boundaries. This situation may increase advected export of moisture. Thus this advection will yield more rainfall in the neighboring catchments (Savenije, 1996).

Finally, conserving forest, vegetation cover and evaporating capacity are very important for water resources management in sensitive areas. Retaining moisture, soils and nutrients are the most important watershed activities for the maintenance of the rainfall (Savenije, 1996).

Establishing typical rainfall runoff relationship for a given catchment is still a problem for present day hydrologists. Especially, it becomes more difficult for a semi arid or an arid catchment, because of the complexity of transformation process of rainfall to runoff. It is also affected by rapid continuous changes in land use / land cover taking place due to several anthropogenic and economic activities (Parida et al., 2006).

An artificial neural network (ANN) model has been made for understanding the forecasting future response behavior of a semi arid catchment in terms of runoff coefficient. This model has forecasted the runoff coefficients for the rapidly urbanizing Notware catchment system in Botswana. Runoff coefficients were computed from 1978 to 2000 by water balance technique. These have been used to develop the optimal neural architecture for network. This developed network has been used to simulate runoff coefficients. The network was used to forecast the runoff coefficients up to 2020. It was found that while the simulated runoff coefficients for the period 1978-2000 showed an increase of 3% per year, the forecasted runoff coefficients for next 20 years showed an increase of about 1% per year. That explains us that the catchment is likely to see a reduction in the yield in the next two decades. It was also found that from the weights attributed to various input variables which used for simulation, 48% contribution comes from climatic factors (average basin rainfall, evaporation, temperature), 52% comes from the land use / land cover (field soil moisture capacity, percentage urbanization) (Parida et al., 2006).

The distribution approach of peak flow is derived from a distribution of rainfall value, runoff coefficient and a unit hydrograph. It is an alternative methodology for streamflow frequency estimation. The advantages of the derived distribution is that the clear interpretation of the parameters which are well-known hydrological concepts. The derived frequency distribution approach plays an important role in the regional flood scaling studies. Gottschalk and Weingartner (1998) derived an expression for the distribution function of peak runoff. This expression combines results of frequency analysis of rainfall volumes with the concepts of runoff coefficients and the unit hydrograph. In their study, precipitation data have long record period and are spatially denser and more uniformly distributed. Streamflow data are related to the antecedent moisture condition in the catchment, and the catchment response to a precipitation input. Statistical parameters of the precipitation samples generally have uniform spatial distribution. These point values are spatially interpolated. Hence regional model is established for the frequency of extreme precipitation. However, runoff formation process is of a local character. It is directly related with the drainage basin characteristics.

Firstly, rainfall volume was scaled with respect to its duration. It is applied to a gamma distribution. Next, beta distribution is applied to the runoff coefficient. In their study the runoff coefficient is considered to be a stochastic variable. The distribution function of the runoff coefficient is a reflection of the physiographic characteristics of the catchment and its climate. The hydrograph characteristics are considered to be deterministic variables (Gottschalk and Weingartner, 1998).

17 small Swiss catchments (comprising 192 flood events), whose unit hydrographs had been determined, were used for testing and validating the derived distribution approach. These drainage basins are grouped according to physiographic conditions. Four groups can be identified, namely alpine, pre-alpine, midland, and southern alpine basins. These four groups showed different derived distribution functions for peak runoff. Results showed that runoff response of these basins were very different in relation to both the distribution of the runoff coefficient and hydrograph characteristics. The distributions of precipitation volume for different durations are similar in three of four groups. The differences in the distribution of peak runoff were explained mainly by the differences in the distribution of runoff coefficients (Gottschalk and Weingartner, 1998).

Gottschalk and Weingartner (1998) said that observation used in this study did not give any evidence of dependence among variables (such as runoff coefficient, precipitation volume and maximum ordinate of the unit hydrograph) and between the runoff coefficient and precipitation duration.

Runoff coefficient is widely used for generating runoff. It is also an important parameter in hydrologic design. Event based derived flood frequency models use event runoff coefficients. (e.g. Sivapalan et al., 2005). They are useful for understanding the flood frequency controls in a particular hydrologic or climatic regime.

Merz et al. (2006) calculated the runoff coefficient from hourly runoff data and hourly precipitation including rainfall and snow. The aim of this study was to analyze the spatio-temporal variability of runoff coefficients from data sets of 50000 events in 337 Austrian catchments for areas ranging from 80 to 10000 km^2. They have been analyzed over the period of 1981 – 2000. The results show that the spatial distribution of runoff coefficient is highly correlated with mean annual precipitation, but weakly correlated with land use and soil type. Beta distribution has been fitted excellently to the temporal distribution of runoff coefficients. The spatial patterns, which match six climatic regions of Austria, have been exhibited with the parameters of the distribution.

Event runoff coefficients increase with event rainfall depths and antecedent rainfall in each of the regions. But the differences between the event runoff coefficients in the regions are larger than those between events of different size (Merz et al., 2006). They analyzed runoff coefficients of different flood types. The results indicate that runoff coefficients increase for flash floods, short rain floods, long rain floods, rain on snow floods and snowmelt floods, respectively. The main controls on the event runoff coefficient are the climate and the runoff regime through the seasonal water balance, hence antecedent soil moisture in addition to event characteristics. Soil and land use affect runoff coefficient to a lesser degree (Merz et al., 2006).

Although the runoff coefficient is the key concept in hydrology science, most of the regional scale studies have analyzed a limited number of events. But Cerdan et al. (2004) analyzed 345 rainfall-runoff events in different size catchments in France. Results indicate that the larger the catchment area is, the smaller the runoff coefficient is. They also said that there exist numerous studies about runoff coefficient of plot scale. But it can be very difficult to upscale these estimates to the catchment area. Dos Reis Castro et al. (1999) examined the runoff coefficients of the catchments, which have different basin areas, on basaltic plateau in southern Brazil. Naef (1993) analyzed a number of largest floods in 100 Swiss catchments and concluded that the interactions of catchment conditions and runoff coefficient are very complex. Thus they can be treated as random numbers. They concluded that the differences in runoff coefficients can be explained by grouping catchments according to their physical characteristics. There are some predictive empirical equations for the event runoff coefficient such as SCS curve number method and the Lutz (1984) method, which is used in Germany. Hence their applicability range is not clear all the time (Blöschl, 2005).

Gregory and Walling (1973) and Reimold (1998) stated that it is necessary to express the catchment characteristics in quantitative terms and correct natural equation to understand the relationships in basin morphological systems and in process response systems.

Ritter et al. (1995) said that flow is significantly related to many components of basin and network morphometry, but it is hard to explain them with single values. Carlston (1963) stated that there is a very close relationship between mean annual flood and the drainage density. It was examined in 15 small basins in the USA. On the other hand, the rate of base flow was inversely related to drainage density in large basins. Morisawa (1967) examined 96 basins in 6 different locations of eastern USA. A relationship ($Q=aL^b$) is estimated between mean annual discharge (q) and longest stream length (L). Patton and Baker (1976) demonstrated relationships between drainage density, channel frequency, basin magnitude, relief ratio, ruggedness number and peak flow in several regions of the USA. The prediction accuracy of the regression equations was up to $R^2=0.92$. Costa (1987) examined the basin morphology with the floods in the USA, which have long record period. Results showed that they occurred in the areas, which had exposed bedrock and high relief in semiarid to arid climates. Berger and Entekhabi (2001) investigated the relationships between physical characteristics and the hydrologic properties of basins. Median slope, relief ratio, drainage density, infiltration capacity, wetness ratio and saturated zone efficiency index (physical characteristics) estimated a runoff ratio with an R^2 of 0.90 in 10 basins in the USA. Sankarasubramanian and Vogel (2002) demonstrated a relationship between runoff ratio and potential evapotranspiration, average slope, relative infiltration capacity and drainage density at 1305 basins across the USA with an R^2 of 0.71. Apaydın et al., (2006) refer to the study of Ward and Trimble (2004) in their study. They found that the 100 year recurrence interval discharge, Q_{100} (m^3/s), is related to the area (A), the basin elevation E (m) and the basin form factor (BSFF) as $Q_{100}=0.471A^{0.715}E^{0.827}BSFF^{0.472}$.

Apaydın et al. (2006) developed an algorithm for determining the basin characteristics by using the Arcview software. These basin characteristics are basin area, stream length, basin shape, form factor, circularity ratio, compactness ratio, basin elongation, basin slope, drainage density, relief, basin width and median elevation. Consequently, the most significant difference between the manual and algorithm methods was observed in the total stream length determination. The differences between these two methods were relatively significant in the calculation of contour length, slope, drainage density, median elevation. Otherwise, the differences for the remaining 11 parameters were quite small.

The proportionality method is the simple approach in the assessment of rainfall-runoff relationship. Its simplicity comes from data requirements as rainfall and runoff records. The rainfall-runoff relation was originally suggested by Kuichling (1889). Wong (2002) stated that this concept has been used over 100 years.

Hundreds of methods have been used for obtaining the best result for runoff estimation from rainfall data. Most of these approaches are empirical. Drainage area, main channel slope, drainage density are some of the input requirements of various geomorphologic parameters for these empirical approaches. Chow (1962) and Haan et al. (1994) stated that they are used rather arbitrarily. The simplest linear method relates the runoff rate to the basin area and rainfall intensity through the runoff coefficient.

The main purpose of study of Şen and Altunkaynak (2006) is to understand the relationship between rainfall intensity i and runoff rate Q on a monthly basis. This can be explained as follows

$$Q=CiA \tag{2.1}$$

where C is the runoff coefficient.

All the variables in this formulation except drainage area have hydrological characteristics of the natural water cycle in an area. Dividing both sides of Equation (2.1) by A, the formula can be expressed in terms of hydrological variables. Hence the new formulation becomes;

$$q=Ci \tag{2.2}$$

where q is the drainage area yield, which is direct runoff depth over catchment per unit area. The runoff coefficient can be defined as a ratio;

$$C=q/i \tag{2.3}$$

In the classical 'rational method' it is considered to be a constant, depending on characteristics of the drainage basin (e.g. Dooge, 1957). Both q and i have stochastic characteristics; so C should have a similar behavior. But in almost every hydrological practice C is assumed as a constant, and is considered as a deterministic value. Chow (1962) said that vegetal cover, soil type and the percentage of the impervious area are the significant ones of the basin characteristics for determining C value.

Before using these equations some hydrological assumptions, comments and simplifications should be considered. These are:

1. Design rainfall is assumed as uniformly distributed over the drainage area. This assumption might be valid for small areas, but is not for large areas. To overcome the problem, large drainage areas should be divided into small sub-basins.

2. Kadıoğlu and Şen (2001) stated that the runoff coefficient is not a static value, it changes dynamically according to the environmental conditions. The portion of the rainfall that becomes direct runoff will be different depending on the antecedent soil and surface conditions of the basin.

3. It is possible to obtain runoff coefficient greater than 1.0 due to the addition of surface water, which could be snowmelt or hail. On the other hand, it is the result of inadequate or inaccurate rainfall data. If there exists any groundwater interaction between one or more adjacent catchments, then the runoff coefficient may have values slightly more than 1.0.

Regression line is the most commonly used statistical methodology for calculating the runoff coefficient. In the calculation the following steps are important:

1. The rainfall and runoff measurements are plotted on a rectangular coordinate system. Each point on the scatter has different antecedent and environmental condition. But this distraction is not considered in regression line. Each point is treated equally to obtain the best straight line. Using regression approach also brings some restrictions such as equivalence of variance, independence of deviations of each scatter point from the fitted regression line, a normal distribution, etc. This restrictive assumption leads to biased runoff coefficient values.

2. The regression methodology gives a single slope, which implies the irrespective of seasonality. However vegetation cover and infiltration rates are very important factors on C. In this methodology, C values are considered the same for all seasons and months of the year.

3. A scatter diagram shows the random behavior of the basin. But the runoff coefficient does not change significantly with the physical characteristics of the basin. Antecedent conditions and the rainfall duration affect the value of C. The scatter diagram does not show that as evident.

Equation (2.3) is the basis for the probabilistic runoff coefficient determination. The runoff coefficient is calculated for every case individually by this equation. Thus the rainfall runoff measurement as two different but correlated, time series are transferred to a single time series of runoff coefficient. The relative frequency histogram for the runoff coefficient series can be obtained. The graph is very good for determining different runoff coefficients as follows:

1. The mode value of the frequency diagram gives the most probable runoff coefficient.

2. The standard deviation shows the dispersion of the runoff coefficient. The skewness coefficient explains the non symmetric behavior of the diagram.

3. As the weighted average of each class, the arithmetical average of the runoff coefficient can be calculated with histogram.

The rainfall runoff processes are not deterministic; rather they are probabilistic or stochastic processes. So all variables in Equation (2.3) have not only averages, but also have other statistical parameters such as standard deviations.

Taylor (1915) stated that perturbation methodology has been used in the studies which concern turbulent flow in channels. An assumption is needed to apply this method, and it is that, the variable has random fluctuations (perturbations) about its average value. Thus, hydrological variables q, C and i in Equation (2.3) are considered to have two components as averages and fluctuations.

$q=q_{ave}+q'$, $C=C_{ave}+C'$ and $i=i_{ave}+i'$ where q', C' and i' show deviations from the respective mean values. The substitution of all these variables and deviations in Equation (2.3) gives;

$$q_{ave}=C_{ave}i_{ave}+(C'i')_{ave} \qquad (2.4)$$

$(C'i')_{ave}$ is equal statistically to the multiplication of the cross-correlation ρ_{Ci}, the standard deviations of the runoff coefficient σ_C, and rainfall intensity σ_i. Thus Equation (2.4) becomes

$$q_{ave}=C_{ave}i_{ave}+\rho_{Ci}\sigma_C\sigma_i \qquad (2.5)$$

A single runoff coefficient is estimated as the slope of the regression line. But the dynamic roles of rainfall runoff processes are ignored in such an approach. Kadıoğlu and Şen (2001) examined a statistical approach that is to group the runoff coefficients in terms of months and calculate the average rainfall and runoff from a given data set. Hence, 12 average runoff and rainfall values are plotted as points on the rectangular coordinate system. The connection of these points leads to an irregular polygon. Hoyt (1936) defined this scatter diagram as the rainfall runoff polygon. This is the statistical runoff coefficient concept of the study of Şen and Altunkaynak in 2006.

Some interpretations can be done from such polygons as follows:

1. The lengths of the polygon sides show the change in the average runoff, rainfall and runoff coefficient values for following months.

2. Runoff is assumed to change linearly with precipitation along each side of the polygon. This linearity assumption during a time interval smaller than one year gives more reliable values for calculating runoff value. If there is a narrower polygon, it is considered that the runoff coefficient is uniformly distributed in the basin. In contrast, the wider the polygon, the more heterogeneous is the temporal runoff coefficients for the basin. It implies the nonlinearity in precipitation–runoff relationship.

3. The runoff coefficient along a rising sequence (during rainy months) is usually greater than those of a falling sequence (during non-rainy months). On the other hand, a rising sequence corresponds to precipitation period, but the falling sequence might represent the contribution from groundwater to surface water. Thus causing the runoff coefficient values become greater than one.

4. If the polygon area of the scatter diagram is small, the monthly precipitation is more consistent and the runoff coefficient is closer to a constant.

5. If the overall slope of the polygon from the horizontal axis is small, the precipitation amount that converted to the runoff by the basin system is larger.

The fuzzy approach is based on linguistic uncertain expressions. Mahabir et al. (2003) and Şen and Altunkaynak (2004) found that the fuzzy logic modelling techniques are considerably better than regression equations. In fuzzy logic basis, the hydrological variables are considered in a linguistic manner, in the from of subgroups, each of which is labelled with the fuzzy words such as ‘low’, ‘medium’, ‘big’ etc. Thus, the variable is not considered as a global quantity. But in partial groups that explain more room for the justification of sub-relationships between two or more variables on fuzzy words.

The rational method for runoff calculation from rainfall has been used over 100 years. It is still widely used for various purposes. This method gives acceptable results especially in small drainage areas. In the classical rational method application, the runoff amount is calculated as the multiplication of rainfall and runoff coefficient averages without perturbation. The variability of the rainfall records is not taken into consideration in the classical rational method. Therefore, results show that the calculations including perturbation are always bigger than classical approach. The classical regression approach has some drawbacks which are due to the basic assumption requirements and uncertainty about data. Fuzzy approach provides better estimation than the classical regression rainfall-runoff relationships. The prediction errors of this approach are smaller. In fuzzy model, the runoff coefficient does not appear obviously, but the runoff estimations from rainfall data are achieved with operationally acceptable relative error limits of less than 10% (Şen and Altunkaynak, 2006).

CHAPTER 3

STUDY AREA, DATA, RUNOFF COEFFICIENTS AND BASIN CHARACTERISTICS

The study is conducted on a number of basins in Western Anatolia. There are totally 48 stream gauging stations, used in the study, which come from eight basins (Figure 3.1); two from Afyon Closed, 13 from Büyük Menderes, one from Küçük Menderes, four from Antalya, six from West Mediterranean, four from Aegean, eight from Susurluk and 10 from Gediz Basins.

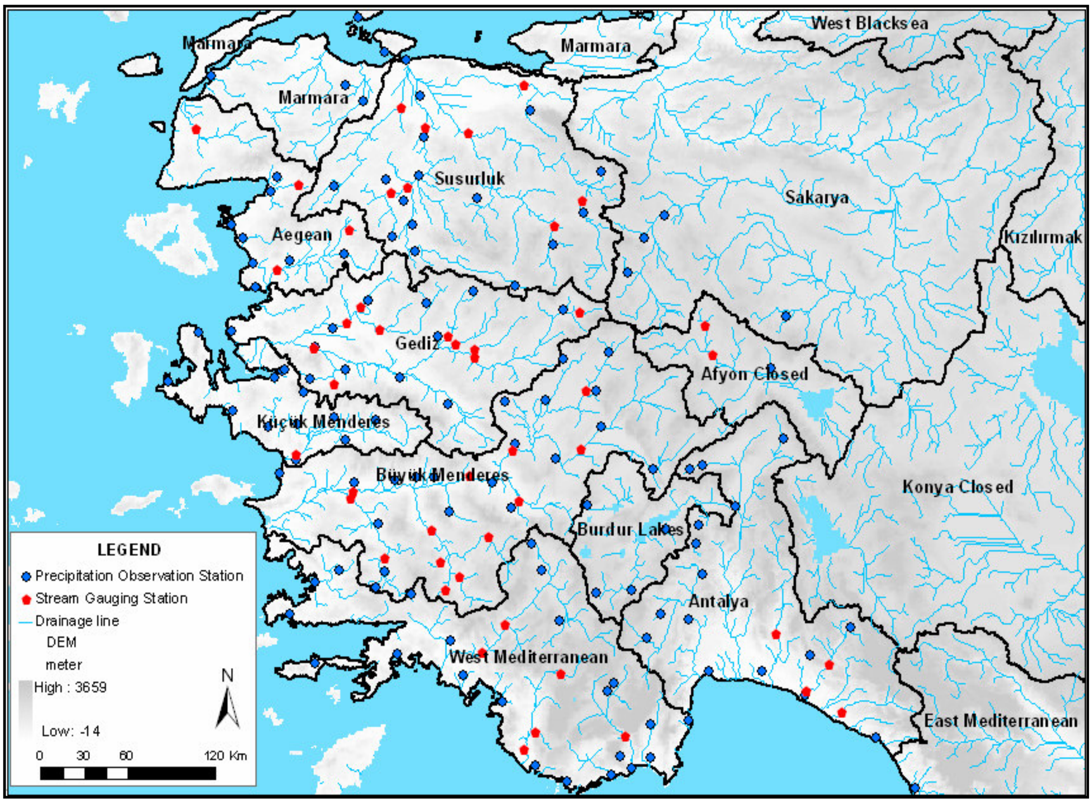


Figure 3. 1 Study area; basins, flow and precipitation observation stations.

3.1 Aegean Basin

Aegean basin is located in the west-northwest of Anatolia. It covers 10000 km^2 area. The basin is surrounded by Marmara at the north, Susurluk at the east, Gediz Basins at the south and Aegean Sea at the west. It lays in the northwest – southeast direction.

The mountains are in the east – west direction. The highest mountain in this basin, which is located in the north – west of Edremit, is Kazdağı with 1767 m altitude. There are lots of streams, which drain the water of the basin to Aegean Sea. They are generally in east west direction. The most significant ones are Kara Menderes, Tuzla, Edremit, Havran, Burhaniye, Madra, Bakırçay and Güzelhisar streams, which are located from north to south respectively. Bakırçay stream has the largest drainage area with 3326 km^2.

The climate type of Aegean Basin is between continental and Mediterranean climates; winters are worm and rainy, summers are hot and arid. The most amount of rain falls in December and January. The position of the mountains, which lay perpendicular to the sea, causes plenty of rainfall inside the basin. The differences between the temperature of sea and the temperature of air affect rain. The temperature of the sea is higher than that of the air, thus the clouds, which come from the sea, produce rain on the continent in winter. On the contrary, in summers the temperature of air is higher than the temperature of sea, hence the clouds do not form rain on the continent (DSİ, 1963).

3.2 Susurluk Basin

Susurluk Basin is in the northwest part of the Anatolia. It has geographical coordinates between 39^{O} 01’ - 40^{O} 23’ North Latitudes and 27^{O} 10’ - 29^{O} 50’ East Longitudes. It is surrounded by Murat, Gümüş, Yirce and Uludağ mountains at the east; Şaphane and Simav Mountains at the south; Madra and Deliçal mountains at the west; Karadağ and Mudanya mountains at the north, which provide partial separation from Marmara Sea. It covers 23824.56 km^2 area that is around 3.05% of the area of Turkey. It has productive soils. The various agricultural products are grown generally in alluvial plains, which are located in the northern part of the basin.

The climate of the basin is generally affected by Marmara and Aegean Seas. It has generally typical Mediterranean climate. It is hot and arid in summer, warm and rainy in winter. Susurluk Basin has changing topography, thus the climate can be changeable from one place to another. The distribution of the precipitation in the basin is different due to topography. The most amount of the precipitation falls in winter.

The elevations of Karacabey and Mustafa Kemalpaşa plains change between 5 m and 50 m. Uludağ is the highest mountain in the basin with 2543 m. The other mountains are Şaphane, Alaçam, Simav and Madra mountains with 2121 m, 1615 m, 1664 m and 1338 m respectively. Plains between these mountains have different size areas. They are namely Tavşanlı, Simav, Sındırgı, Bigadiç, Balıkesir, and Susurluk Plains.

The drainage of this basin is mainly provided by Kocasu stream to Marmara Sea. The other streams are Simav, Madra, Emet, Adranos and Nilüfer. There are natural lakes in the basin. The most important ones are Apolyont, Manyas and Simav Lakes, which have fresh water. The regimes of the rivers in the basin are irregular, such that the discharges of the rivers increase in winter and fall, they reduce and become almost dry in summer.

The heavy rainfalls coming in short time cause floods, which occur especially in the plains at the north part of the basin. Although minimum water depth of Apolyont Lake is 29 cm, it increases to a maximum of 489 cm in winter. These values reveal the change in precipitation. Most of the surface water in the basin is due to heavy rain.

Susurluk, Manyas, Mustafa Kemalpaşa and Karacabey regions, which are at the north part of the basin, have good groundwater reservoirs with respect to quantity and quality. Simav basin, which is at the southern part of the basin, has also large groundwater resource (Topraksu, 1971).

3.3 Gediz Basin

Gediz Basin is in the Aegean Region. It is surrounded by Aegean, Susurluk and Küçük Menderes Basins, and has geographical coordinates between 38^{O} 04’ - 39^{O} 13’ North Latitudes and 26^{O} 42’ - 29^{O} 45’ East Longitudes. It covers 17218.95 km^2 area that is around 2.2% of the area of Turkey (Topraksu, 1974).

The elevations of Selendi and Üzümlü Plains are 415 m and 625 m, respectively. They are located at the upstream of the basin. The elevation in the basin decrease towards the west. It is approximately 100 m in the middle of the basin, and becomes 2.5 m in Menemen Plain.

Murat Mountain has the highest elevation with 2312 m at the east. The elevations of mountains are 2159 m, 1664 m, 1555 m, 1553 m and 1510 m for Bozdağlar, Simav, Umurbaba, Çulha and Nif Mountains. The elevations of mountains decrease from east to west (Topraksu, 1974).

Gediz Basin has generally typical Mediterranean climate. It is hot and arid in summer, warm and rainy in winter. Precipitation falls mostly in winter. The largest amount of precipitation falls on Kemalpaşa with 1058 mm, and the smallest amount falls on Saruhanlı with 449 mm (Topraksu, 1974). January and February are the rainiest months of Gediz Basin and the driest months are July and August (Web 1).

Gediz River, which arises from the south-east of Gediz Town in the Aegean Region, is the second biggest river of the Aegean Region. It gets its source from the Murat and Şaphane Mountains in the West Anatolia Region (Web 1). There are several creeks, which drain to Gediz River. They are Selendi, Deliniş, Demrek, Gördes, Medar, Kumçay Creeks located at the north; and Kocaçay, Alaşehir, Derbent and Nif Creeks at the south (Topraksu, 1974).

3.4 Küçük Menderes Basin

Küçük Menderes basin is located in south of İzmir in western Anatolia. It is shaped in a graben debris field along the east-west direction. It has geographical coordinates between 37^{O} 53’ - 38^{O} 23’ North Latitudes and 27^{O} 10’ - 28^{O} 23’ East Longitudes (DSİ, 1996). Küçük Menderes River is born on the upper parts of Kiraz town and pours to the sea at the boundaries of the City of Selçuk with an annual average flow rate of 11.5 m^3/s. The basin covers an area of 3502 km^2 (Web 2).

The north, south and west parts of the basin are surrounded with mountains. As a result of changes in ground elevations, the mountainous fields are not suitable for settlement and agriculture. As for the streams and branches, they generally flow in the north-south direction. Küçük Menderes River basin has a typical Mediterranean climate. It is warm and dry in summer and rainy and mild in winter (Web 2). The types of rainfall observed in the region are of convective at depression areas in the inland parts, and of orographic in the form of showers at the shore and at high elevations. The mean annual precipitation is high at the shore because of orographic conditions. The mean annual precipitation of this basin is 705 mm and the mean annual temperature is 16.9^{O}C. Annual precipitation is also high in the vicinity of Bozdağ and Çınarbaşı located in the inland areas, in comparison to nearby areas.

The percentage of runoff due to snowmelt is quite small for Küçük Menderes River (DSİ, 1996).

3.5 Büyük Menderes Basin

Büyük Menderes Basin has geographical coordinates between 37^{O} 07' - 38^{O} 55' North Latitudes and 27^{O} 00' - 30^{O} 35' East Longitudes. It is surrounded by Gediz Basin at the north, Sakarya Basin at the northeast, Afyon Closed and Antalya Basins at the east, Burdur Closed Basin at the southeast and West Mediterranean Basin at the south.

Büyük Menderes River basin has populated farmland and rapidly developing urban and suburban areas. Its agriculture and industrial sectors are highly developed and therefore water management in this region is very important. The basin has a watershed area of 24976 km^2. Total population of the basin is 2.5 million and 37% of this population is involved in agricultural activities. Mean annual precipitation in the basin is 635 mm. Precipitation occurs mainly in winters while during the summer irrigation period there is very little rain. This high change in precipitation causes frequent droughts and floods in the region. Due to increase in population and agricultural practices, more water is needed in the catchment (Web 3).

3.6 Afyon Closed Basin

Afyon basin has areas in Aegean, Middle Anatolia and Mediterranean Regions. Largest part of the basin is in the inner West Anatolia part of the Aegean Region. The east and the northeast parts of the basin are in the Middle Anatolia Region. It has geographical coordinates between 38^{O} 04' - 39^{O} 09' North Latitudes and 30^{O} 02' - 31^{O} 51' East Longitudes. It is surrounded by Sakarya Basin at the north, Antalya Basin at the south, Konya Closed Basin at the east and Büyük Menderes Basin at the southwest. It includes the centers of Afyon and Konya provinces; Sincanlı, Şuhut, Çay, Bolvadin and Sultandağı (İsaklı) districts of Afyon province and Akşehir district of Konya province. It covers 7738.90 km^2 area that is around 1 % of the area of Turkey. The length and the width of the basin are approximately 130 km and 20 km, respectively. The basin is also surrounded by Emir and Türkmen Mountains from the northeast, İlbudak Mountain from the northwest, Sultandağları from the southeast, and Ahır and Kumalar Mountains from the southwest (DSİ, 1998).

Its water discharges to lakes and marshes, therefore it is a closed basin. A large part of its water is drained to Eber and Akşehir Lakes by Akarçay Stream, which is the main stream of the basin. There are also other streams in the basin, whose discharges decrease in summer, or disappear totally. Water, which comes from Sultandağları and surrounding little creeks, is gathered in Akşehir, Eber and Karamut Lakes. Water of Akşehir Lake is salty. Thus, it is not used for drinking and for other usages. Eber Lake discharges its water to Akşehir Lake and it has fresh water. Afyon Closed Basin is not arid as much as Tuz Lake and Konya Basin (Web 4).

The elevations of Sultan, Emir and Kocatepe Mountains are 2520 m, 2307 m and 1900 m respectively, and there are Afyon, Şuhut and Sincanlı Plains among them. The typical climate of the basin is Middle Anatolia climate. The characteristics of the Aegean Region climate also affect this basin. The agriculture has the most important role in economy in that region. But the climatic conditions make it difficult for the agriculture. Summers are arid and hot. Winters are cool and rainy. The amount of precipitation at southeast and south is more than at the north. The larger amount of the precipitation falls in winter and spring. In general, precipitation occurs heavily. A large part of precipitation becomes surface water at the mountain area with high slope (Topraksu, 1983).

3.7 Antalya Basin

Antalya basin is in the Mediterranean Region. The water of the basin is drained to Mediterranean Sea by Boğaçay, Kırkgözler Springs; Düden, Aksu, Köprüçay, Manavgat, Karpuz, Alara, Kargı, Oba and Dim streams. It has geographical coordinates between 36^{O} 30’ - 38^{O} 28’ North Latitudes and 30^{O} 10’ - 32^{O} 22’ East Longitudes. It includes center of Antalya and Isparta provinces; Bucak and Ağlasun districts of Burdur; Serik, Manavgat, Alanya, Gündoğmuş, Akseki, Korkuteli districts of Antalya; Atabey, Eğridir, Sütçüler, Gelendost, Yalvaç, Senirkent and Uluborlu districts of Isparta province. It is surrounded by Sultan Mountains at the north, Alanya district and Taurus Mountains at the east; Korkuteli, Bucak, Ağlasun, Uluborlu, Senirkent districts, which are surrounded by Beydağları and Katrancık mountains, at the west; the gulf of Antalya at the south. It covers 20020.36 km^2 area that is around 2.56% of the area of Turkey. It has generally mountainous topography at the east, west, center and north. Because of that, the average elevation of the basin is higher than 1000 m. It is close to average elevation of Turkey, which is 1132 m. Dedegüldağı has the highest elevation with 2935 m at the east. There are coastal plains at the south with 100 m average elevation. The average elevations of plains change between 800 m and 1250 m at the west and north of the basin.

The floods generally happen in Boğaçay and Aksu streams. One of the reasons for flooding is heavy rain. Secondly, the discharges of the streams increase by snowmelt in spring. Thirdly, the southwest wind forms big waves at the coast.

There are two types of climate in Antalya Basin such as the typical Mediterranean climate at the coastal region and the continental climate at the upstream of the basin.

The amount of the precipitation decreases from south to north. Although annual total precipitation is 1000 mm at coastal region, it decreases to 600 mm at northern part of the basin. There are mountains at the northern part of basin, which prevent forming larger amount of precipitation on inner part of the basin.

Precipitation falls mostly in winter. The annual total precipitations are 1030.5 mm for Antalya, 1038.3 mm for Manavgat and 1041.8 mm for Alanya. The annual total precipitation charges between 500 mm and 750 mm for plateaus of the basin. The larger amount of surface water is formed by heavy rain.

Antalya Basin has plenty of water resources. In addition to the coastal streams mentioned before, there are Pupa, Hayran, Yalvaç, Korkuteli streams at the upstream of the basin. Eğridir, Kovada, and Kestel Lakes are also in this basin. Mamak Lake is a seasonal lake. Boğaçay, Çiftçialanı, Manavgat, Alanya, Korkuteli, Bozova, Hayran, Gelendost, Uluborlu and Senirkent plains have groundwater reservoirs (Topraksu, 1970).

3.8 West Mediterranean Basin

West Mediterranean basin is in the south – west of Anatolia. The basin length is approximately 300 km from west to east. The largest width is 85 km and the smallest is 13 km from north to south. It covers 20900 km^2 area of Anatolian peninsula and 53 km^2 area of islands, with a total of 20953 km^2, which is around 2.75% of the area of Turkey. The basin is surrounded by Mediterranean and Antalya Basins at the east, Burdur Lake and Büyük Menderes Basins at the north, Aegean Sea at the west and Mediterranean Sea at the south. It includes Muğla province and some part of Antalya, Burdur and Denizli provinces.

The high mountains are in the eastern part of the basin. The elevations of the mountains become low at the west. The highest mountains are Akdağ, Alacadağ, Bey and Tahtalı Mountains with 3024 m, 2338 m, 2738 m and 2373 m respectively at the east. At the west, the mountains are parallel to the sea. The elevations of these mountains are low. The highest one of them is Kavak Mountain with 1368 m. There are deep valleys among the mountains.

Dalaman and Eşen streams are the most important stream in this basin. The other long streams are Sarıçay, Namnam and Alakır streams.

Although the coastal part of the basin has Mediterranean climate, the high plateaus and mountains at the northern part have continental climate. The mountains, which are in the western part of Dalaman stream, are perpendicular to the sea. That region is affected by Mediterranean climate. The continental climate is seen on the high mountains, which are in the eastern and northern part of Dalaman Stream. These mountains lay southeast – northwest direction.

The distribution of precipitation of the basin is different. The plains and mountains at the coastal side of the basin have plenty of rain by southwest wind in the rainy seasons. The high mountains at the east and northeast part of the basin have largest amount of rain in the rainy seasons. The high plateaus are behind the mountains. The amount of rain on them decreases. Annual total precipitation is higher than 1000 mm at the plateaus. The high mountains, which are between the coast and the plateaus, have 2000 mm for annual total precipitation. The basin is generally warm in winter. Akdağ, which is located between Elmalı and Fethiye, has snow some months of year. The coastal side of the basin has very little snow in winter. The highest snow depth in Muğla is 9 cm (DSİ, 1962).

3.9 The Data Used For the Study

3.9.1 Digital Elevation Model (DEM) of the Study Area

There are several elevation data types, which are used in GIS. The widely used ones are vector contour maps, gridded raster elevation models and triangular irregular networks (TINs). The raster elevation models are more common because their production analyses methods are easier (Girgin, 2003).

A digital elevation model (DEM) is a digital representation of topography. It can be represented as a raster or as a triangular representation network. DEMs are built using remote sensing techniques and land surveying. DEM may store the elevation values in different formats such as Geotiff, ASCII and Digital Terrain Elevation Data (DTED). The DEM, which is used in this study, is originated from DTED of the Shuttle Radar Topography Mission (SRTM), which is a joint project between NASA and NGA (National Geospatial-Intelligence Agency) to map the world in three dimensions (Web 5).

In this study, SRTM30-Arc Seconds Global Elevation DEM (SRTM30) dataset is used as the base elevation data for all DEM based analyses. DEM of the study area can be seen in Figure 3.2.

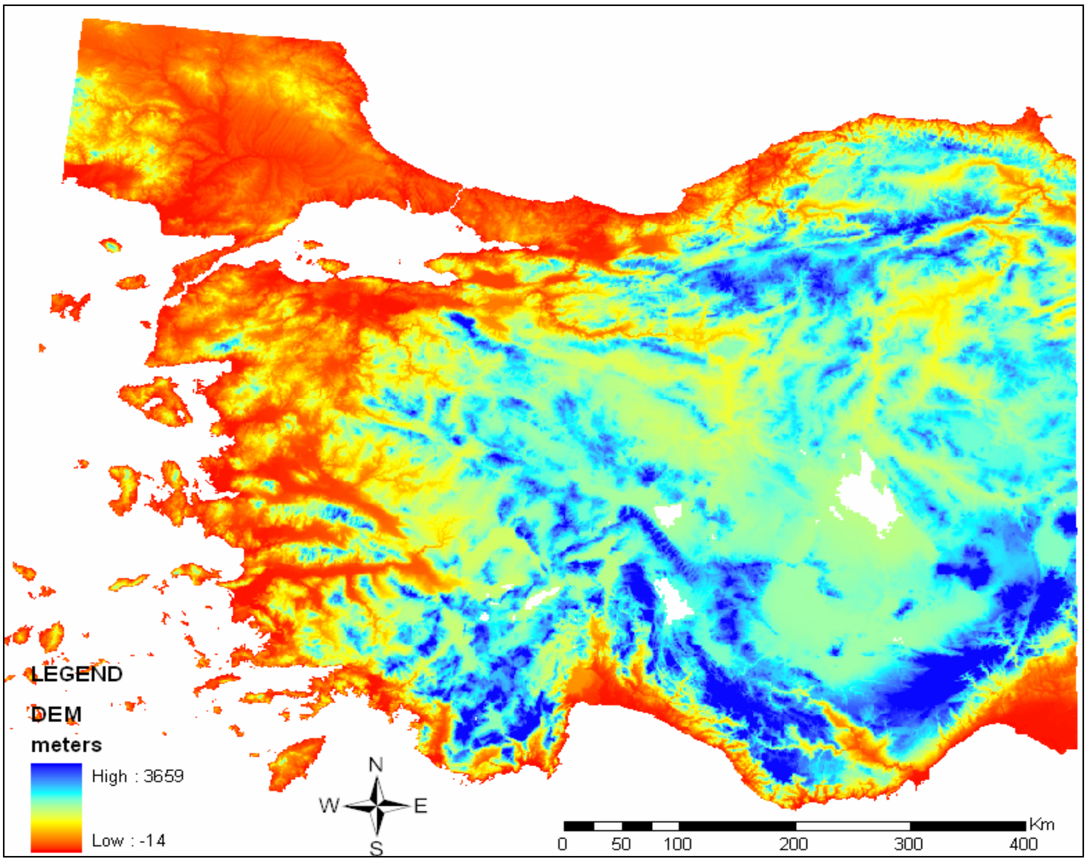


Figure 3. 2 DEM of western and middle Anatolia.

3.9.2 Streamflow Data

The data obtained from General Directorate of Electrical Power Resources Survey and Development Administration (EPRSDA, Elektrik İşleri Etüd İdaresi, EİEİ) include monthly average discharges from 1975 to 2000 (record period of 26 years). Their locations are also taken from EPRSDA. There were a lot of missing records, which were estimated by using upstream or downstream records of stream gauging stations and their area relations in this study.

A total of 48 stream gauging stations are selected in eight basins; two from Afyon Closed, 13 from Büyük Menderes, one from Küçük Menderes, four from Antalya, six from West Mediterranean, four from Aegean, eight from Susurluk, 10 from Gediz (Figure 3.1). The monthly, seasonal and annual average discharge values are used to form a database, which has 17 fields.

3.9.3 Precipitation Data

The data of the precipitation stations and their locations are obtained from State Meteorological Work (SMW, Devlet Meteoroloji İşleri, DMİ). 122 precipitation observation stations (POSs) with records of monthly precipitation data for 26 years are used in this study (Figure 3.1). The monthly and annual total precipitation values are inserted to a database under 13 attributes.

3.9.3.1 Estimation of the Missing Precipitation Data

Many precipitation stations have short breaks in their records due to the lapses in the observation, human errors and instrumental failures. Missing records are estimated by using the available records of the surrounding stations, which are as close as possible. There are three methods for this purpose such as the normal ratio, the arithmetic mean and the weighted averaging methods (Usul, 2001).

In this study, the normal ratio method is used for estimating the missing precipitation data. This method is used when the normal annual precipitation at any of the index stations differs from that at the station with the missing record by more than 10 % (Usul, 2001). Missing precipitation (P_x) values are calculated using the formula given below.

$P_x = 1/3 ((N_x/N_a*P_a) + (N_x/N_b*P_b) + (N_x/N_c*P_c))$ (3.1)

a, b, c are the index stations.

N_a, N_b, N_c are normal annual precipitations for the nearest three POSs to POS that has missing data.

P_a, P_b, P_c are the precipitation values of index stations for the missing period.

N_x is the missing annual precipitation value.

3.9.3.2 Areal Mean Precipitation

The data obtained at precipitation gauges give only point values of precipitation. But in most hydrologic studies areal mean values are needed. There are several methods to distribute the point information of precipitation to the area such as the arithmetic mean, the thiessen polygons and the isohyatal map methods. In this study, the thiessen polygons method is used for finding areal mean precipitation because this method is simple and needs short computation time. In this method; to find the mean precipitation value of a certain region, the polygon areas falling in the region of interest are multiplied by the rainfall depths of the corresponding stations. Then sum of these products is divided by the total area (Usul, 2001).

$P_{ave}= \sum(P_i *a_i) / \sum a_i$ (3.2)

Where P_{ave} is the areal mean precipitation, P_i is the rainfall observed at the i^{th} station, a_i is the in-region portion of the area of the polygon surrounding this station. In this method all the stations in and out of the area are taken into consideration (Usul, 2001). Thiessen polygons of the study area are shown in Figure 3.3.

3.10 Delineation of the Watershed Boundaries

A drainage basin is an extent of land where water from rain or snowmelt drains downhill into a body of water, such as a river, lake, dam, sea or ocean. Each drainage basin is separated topographically from adjacent basins by a ridge, hill or mountain, which is known as a water divide or a watershed (Web 6).

For determining the watershed boundaries, a suitable digital surface model is needed. For this purpose, in this study, a digital elevation model (DEM) obtained from SRTM30 is used.

First of all the selected DEM (SRTM 30) is pre-processed and made suitable for hydrologic modeling. To do this, sinks are found, removed, and then inaccurate elevation values are corrected in the DEM. The deterministic-8 (D8) method is used for calculating flow direction and flow accumulation grids. D8 method is a widely used method for drainage network and watershed boundary extraction from DEM (Girgin, 2003).

The grid cell size of SRTM30 DEM is 30-arc seconds (0.008333 decimal degrees) at X and Y direction, which is equal to approximately one kilometer at the equator. But this dimension is not constant. It decreases in the longitudinal direction as latitude increases. It is important that the variation in the grid cell dimensions should be taken into consideration during the cell based area and distance calculations (Girgin, 2003).

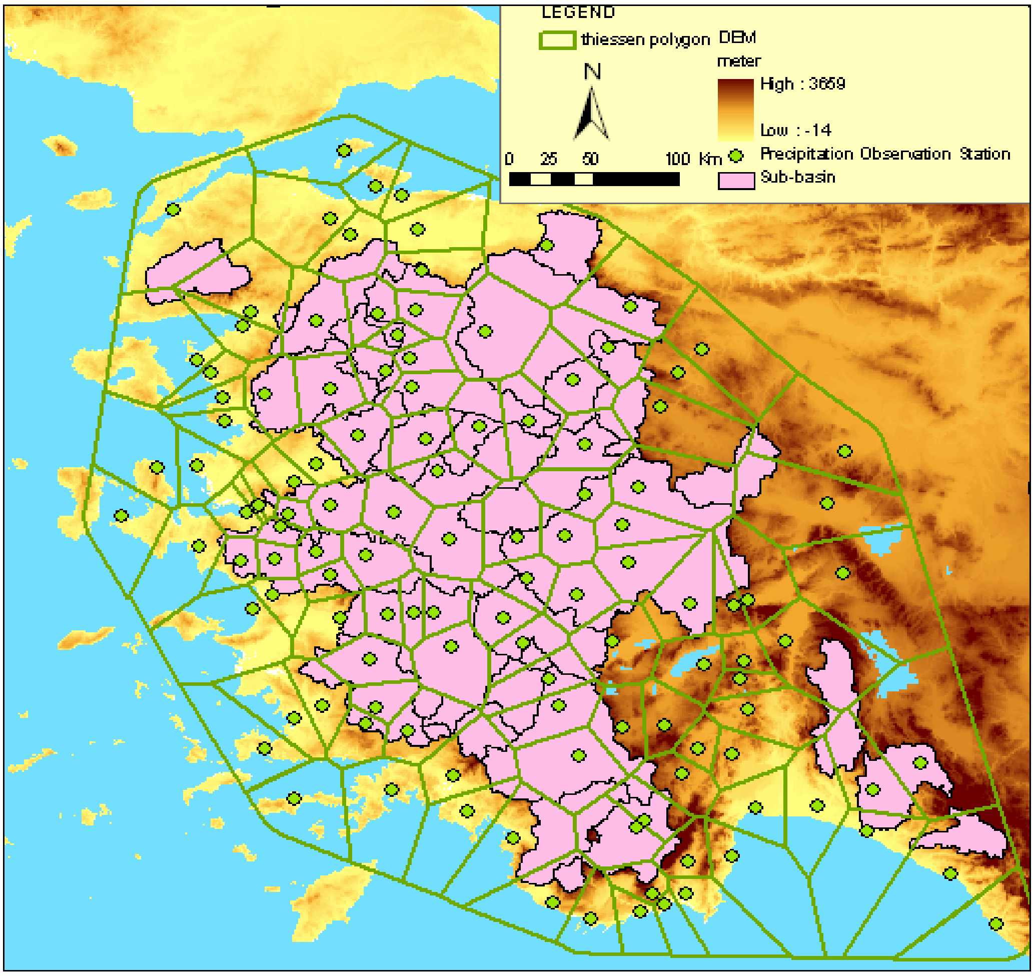


Figure 3.3 Sub-basins used in the study and the thiessen polygons.

USGS (1997) state explicitly, "derivative products, such as slope maps, drainage basin areas and stream channel length, will be more reliable if they are calculated from a DEM that has been first projected from geographic coordinates to an equal area projection, so that each cell, regardless of latitude, represents the same ground dimensions and area as well as other cell". Richardus and Adler (1972), which is referred in Girgin (2003), examined several projection alternatives. The Albers Equal Area (AEA) projection, which is a conical equal area projection, recommended for regions that are predominantly East-West in extent. The DEM of the study area, which is in geographic coordinates, is projected into AEA projection according to this recommendation. Parameters, which are given in Table 4.1, are used for changing the projection of the DEM into the AEA projection.

Table 3. 1 Common parameter values used in Turkey for conical projections (Girgin, 2003).

Parameter	GCM North
1. Standart Parallel (degrees)	40.66667
2. Standart Parallel (degrees)	43.33333
Central Meridyen (degrees)	34
Origin of Latitude (degrees)	*
False Easting (meters)	*
False Northing (meters)	*

*Not stated. It can be used a default value such as "0".

D8 is the most widely used method for drainage network and watershed extraction from DEM. This method requires a DEM that is free of sink. Hence some pre-processing steps are required. Girgin (2003) delineated watershed boundaries for Turkey, while doing so; he saw that lakes behave like "sinks" that draw streams to themselves. He also found out some problems about streamlines during the delineation of watershed boundaries.

In this study the following steps are followed considering Girgin (2003)'s recommendations. D8 method does not consider the sizes of the sinks explicitly; both lakes and sinks are similar features that should be removed from the DEM. From International Geosphere Biosphere Programme (IGBP) thematic map, water bodies are extracted as a separate layer by manual editing, and classified into sinks and on stream water bodies. Sinks are created as a vector layer, which should be converted into raster format. Using reclassification method, this raster sinks layer is reclassified by changing all their grid cell values to 10000 (It should be a different value from the DEM grid cells that has values between -14 and 3488, so sink grid cells are taken as 10000). Sinks raster layer and original DEM are combined. Then the grid cell values of combined DEM are changed by using set_null function of the spatial analyses toolbox in the ArcToolbox. So the grid cells, which belong to sink inland water bodies, are incorporated into the study area DEM as "No Data" values. Then all the sinks in the DEM are filled.

3.10.1 Flow Direction

Flow direction grid shows the directions of the flow from one cell to another cell. Arc Hydro uses D8 (8 directional-flow direction) model. This model is introduced by O'Callaghan and Mark (1984), and it uses elevation values of DEM. D8 method uses the fact that water flows towards lower elevations to define the direction of flow. The lowest elevation around the center cell is searched by comparing the elevation values of eight neighboring cells around the center cell. This procedure is (3*3) matrix operation over the DEM layer. Therefore, at the end of the operation each cell has a value that represents flow direction.

Before applying D8 method, DEM should be free of sink, as mentioned before. The elevations of center cells should be higher than the elevations of the surrounding cells, otherwise the continuity of flow direction is broken. The center cells behave like sinks, therefore they should be raised up in order not to stop the flow. Flow direction grid of the study area is given in Figure 3.4.

3.10.2 Flow Accumulation

After determining flow directions, the number of cells, which are located upstream of each cell, is calculated as a measure of flow accumulation (Girgin, 2003). Flow accumulation values are used to define the streamlines. Small branches have small flow accumulation values. If two branches join to form bigger branches, their flow accumulation values will be added. Flow accumulation grid of the study area can be seen in Figure 3.5. Colors show the different flow accumulation values.

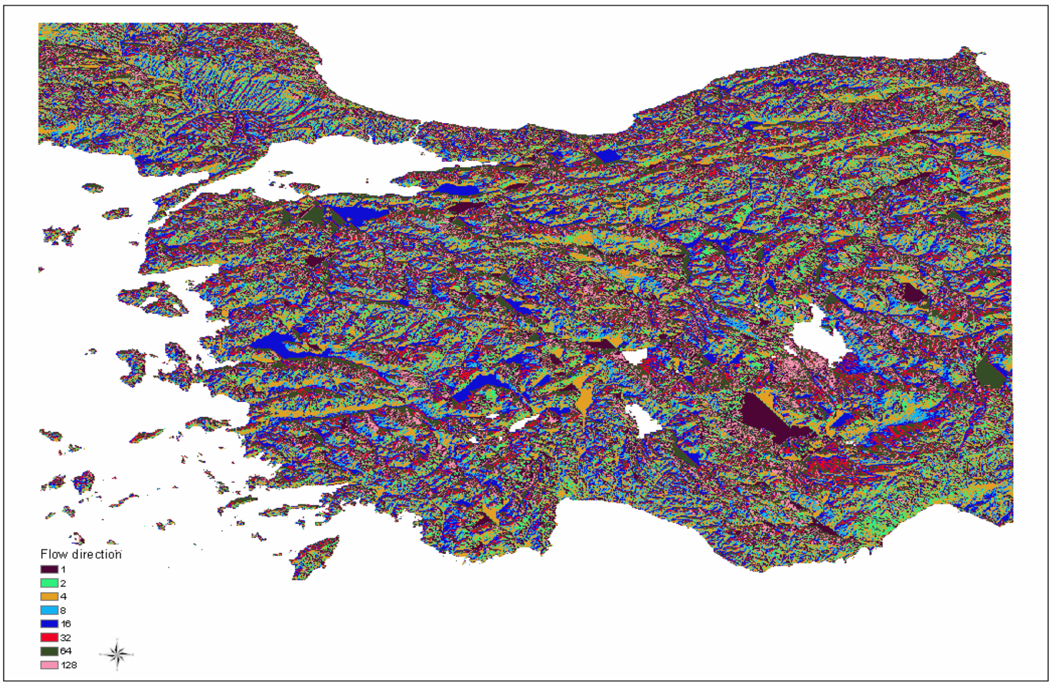


Figure 3.4 Flow direction grid of western and middle Anatolia.

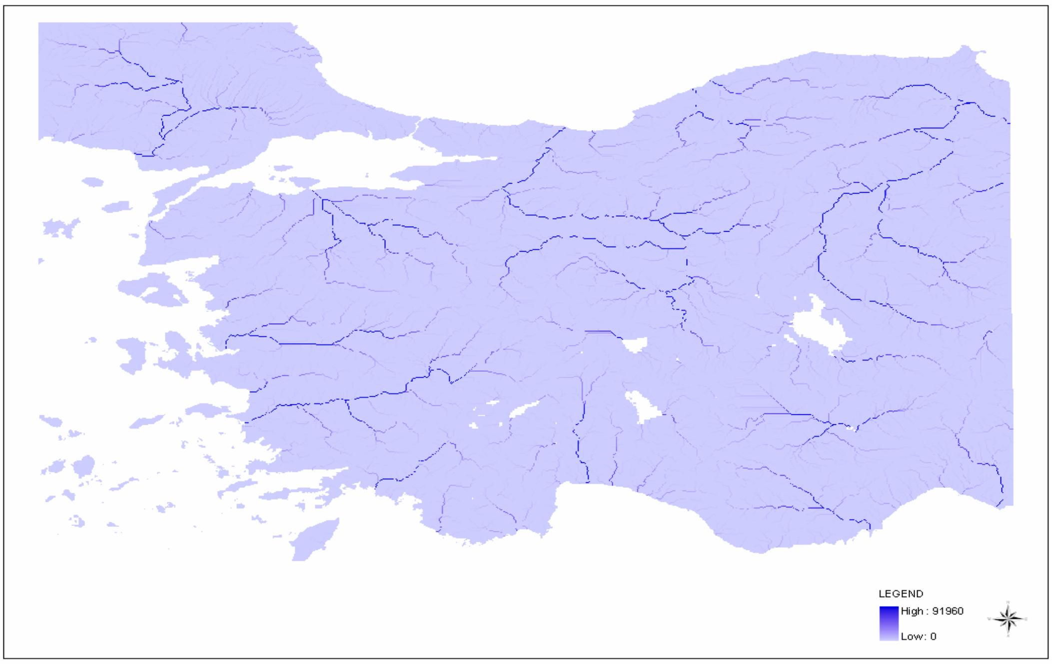


Figure 3.5 Flow accumulation grid of western and middle Anatolia.

3.10.3 Stream Network Definition

The drainage lines, which can be defined as stream, are shown in the flow accumulation network. The streamlines are determined by applying a threshold value to the flow accumulation values and selecting the cells with higher accumulation values. The threshold value is determined by a trial and error procedure.

Figures 3.6 and 3.7 show the stream networks corresponding to different cell threshold values such as 920, 500, 250, and 100 respectively. It is observed that, the streamlines, which are formed by 100 threshold value, fit the streamlines of 1: 500.000 scale map.

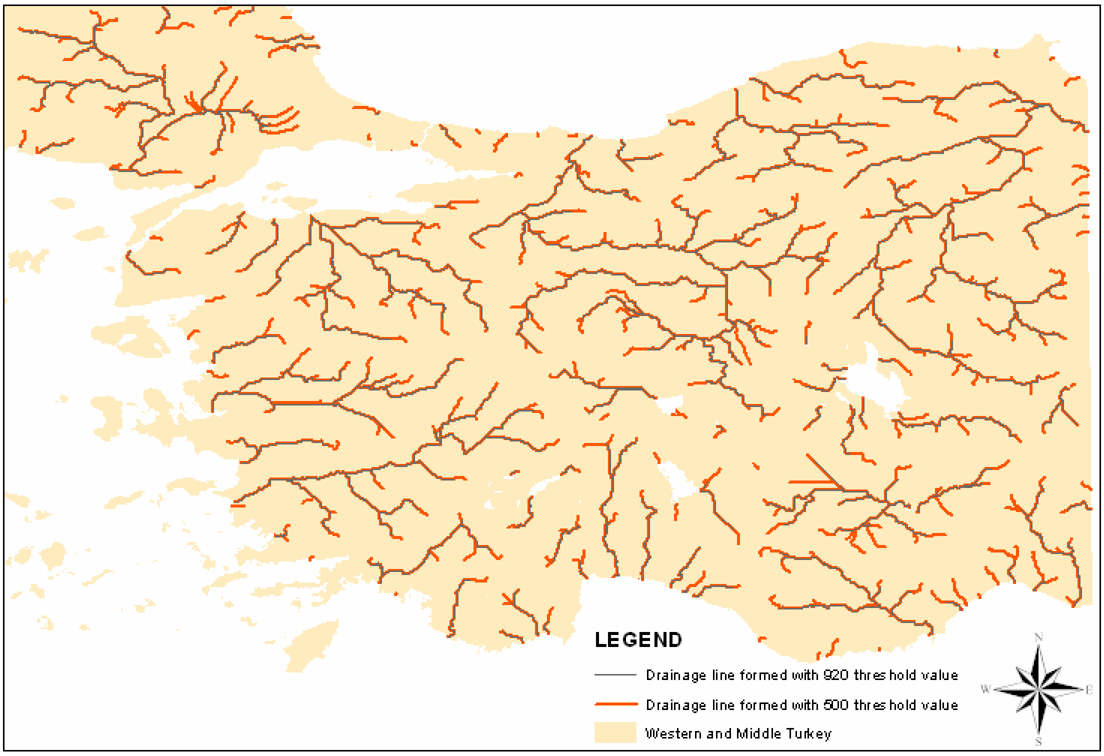


Figure 3.6 Drainage networks obtained from lake-burned DEM with 920 and 500 threshold values.

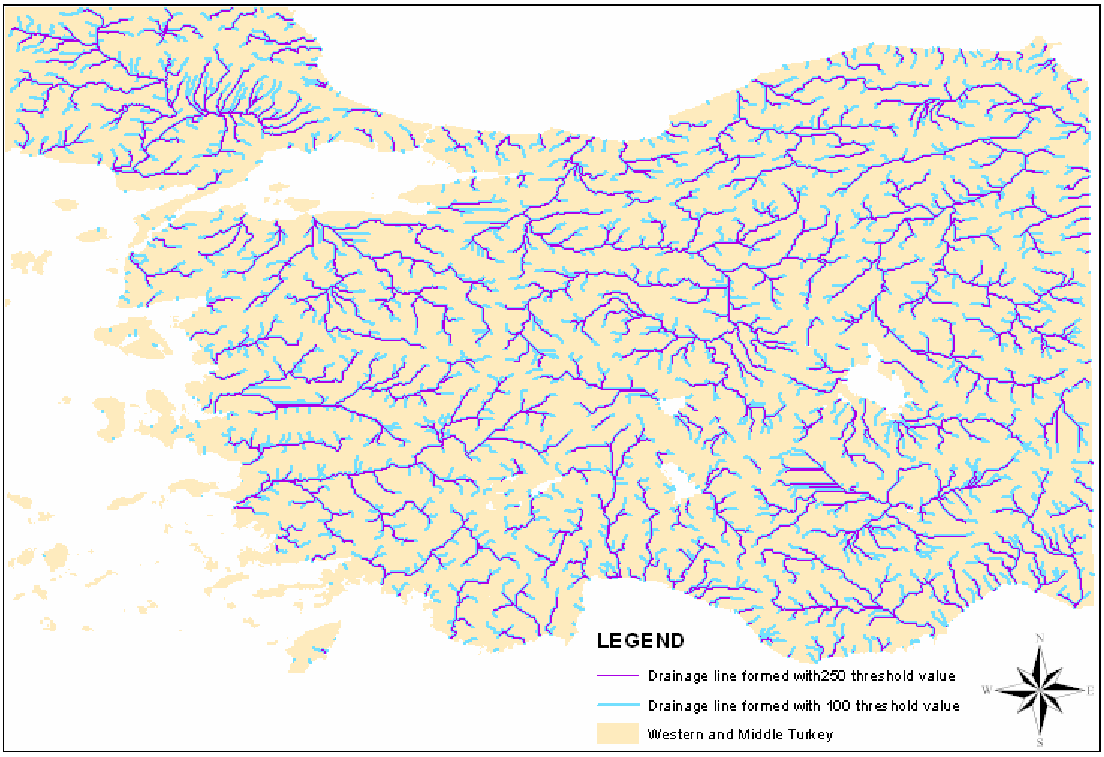


Figure 3.7 Drainage networks obtained from lake-burned DEM with 250 and 100 threshold values.

3.10.4 Basins

As mentioned before, there are eight basins used in the study, which are Afyon Closed, Büyük, Küçük Menderes, Antalya, West Mediterranean, Aegean, Susurluk and Gediz Basins. They are divided into sub- basins for the SGSs chosen for the study. For a stream gauging station (SGS) on a river, the area above that point which passes all its surface waters through this point is called as its sub-basin. The boundary of the basin is the line that separate adjacent basins, which passes through the highest points between them. Sub-basin boundaries can be determined easily from DEM using GIS tools. Arc Hydro extension of ArcGIS software can determine the boundaries of sub-basins from DEM by clicking on every SGS point by ArcHydro point delineation tools. They can be seen in Figure 3.8.

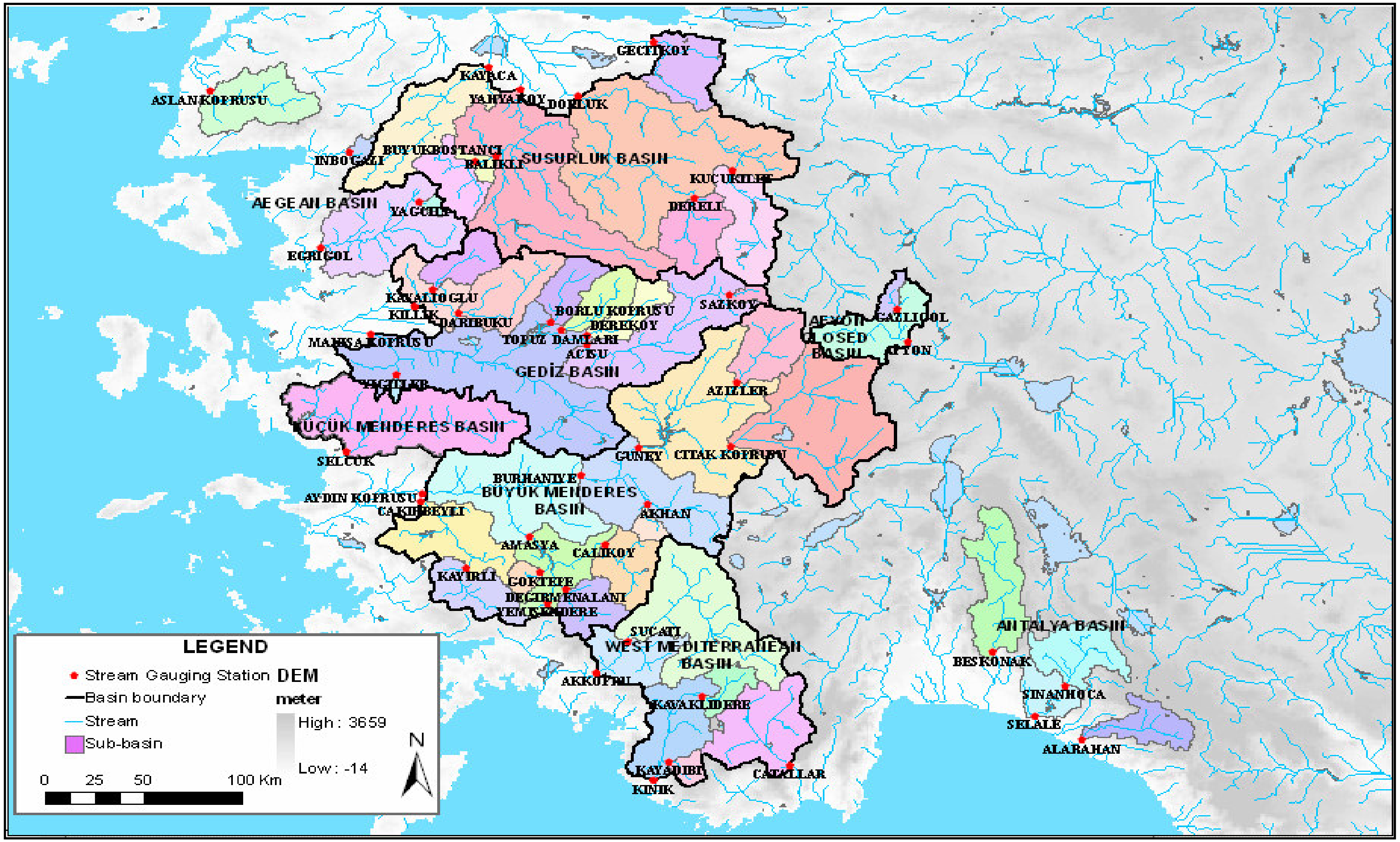


Figure 3.8 Sub-basin boundaries in the study area.

3.11 Automated Runoff Coefficient Estimation

One of the aims of this study is to find runoff coefficient by using synchronous and average of long years of discharge and precipitation data. For that purpose, a program is written with ArcObjects and visual basic programming language. The ArcGIS project application is made for this purpose. This project application consists of two maps, or data frames. One is an overview map of the study area with all sub-basins, drainage network and the DEM of the study area. The other is a detailed map of the drainage area of the selected stream gauging stations, precipitation observation stations (POSs) and their thiessen polygons. When the user picks a SGS name from a drop-dawn list and a certain time, the corresponding basin of the selected SGS will be highlighted on the overview map. The detailed map will zoom to the selected basin and the thiessen polygons layer. An example of selection is shown in Figure 3.9. Pink points show the SGSs and blue ones show POSs.

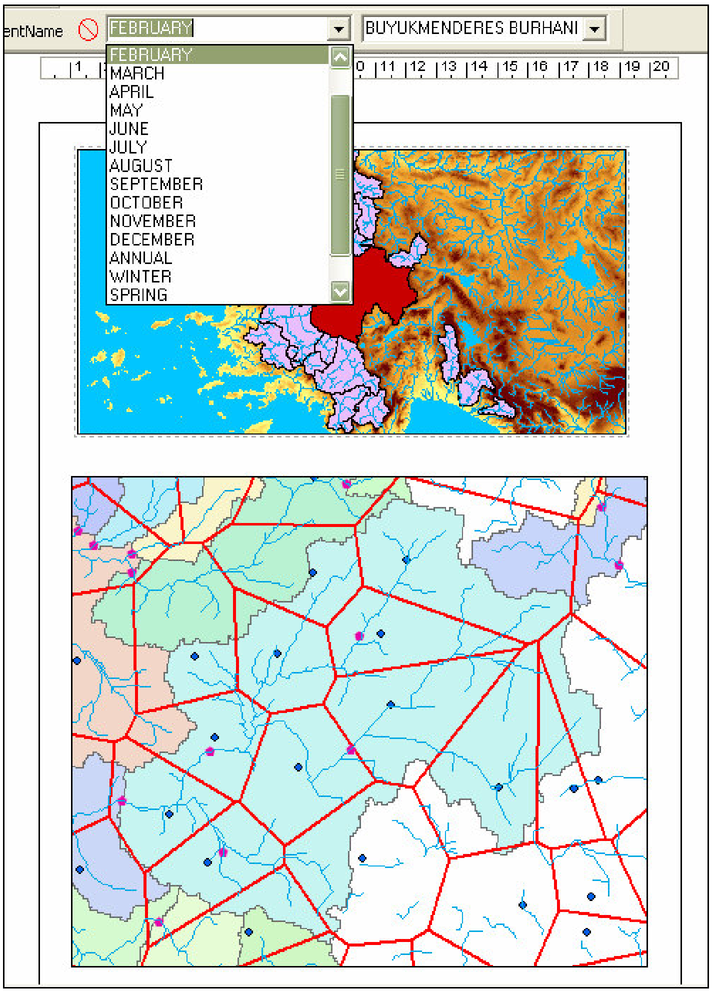


Figure 3.9 Visualization of selected time interval and stream gauging station.

Each basin and its related thiessen polygons are clipped and saved as feature layers. The thiessen polygon areas remaining in the basin are calculated easily by using table operation menu of X Tools Pro extension of ArcGIS software. Then, each polygon area is divided by the total basin area giving the weights of thiessen polygons. These calculations are made for all sub-basins, and the results are added to attribute tables of the clipped layers. Twelve monthly and annual precipitation values are available in the attribute tables of these clipped layers.

The context menu items are formed for monthly, annual and seasonal total precipitation by ArcObject. Unlike a toolbar menu, a context menu is not always suitable on the Arcmap project screen. It only appears when the user has right clicked on object (feature layer) (Figure 3.10).

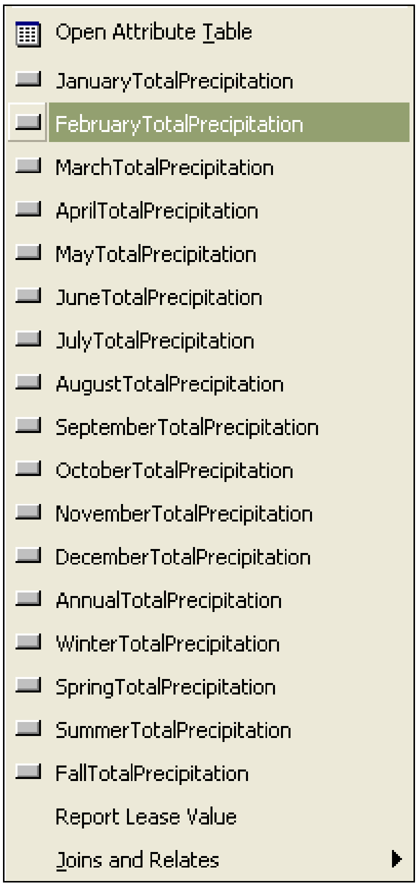
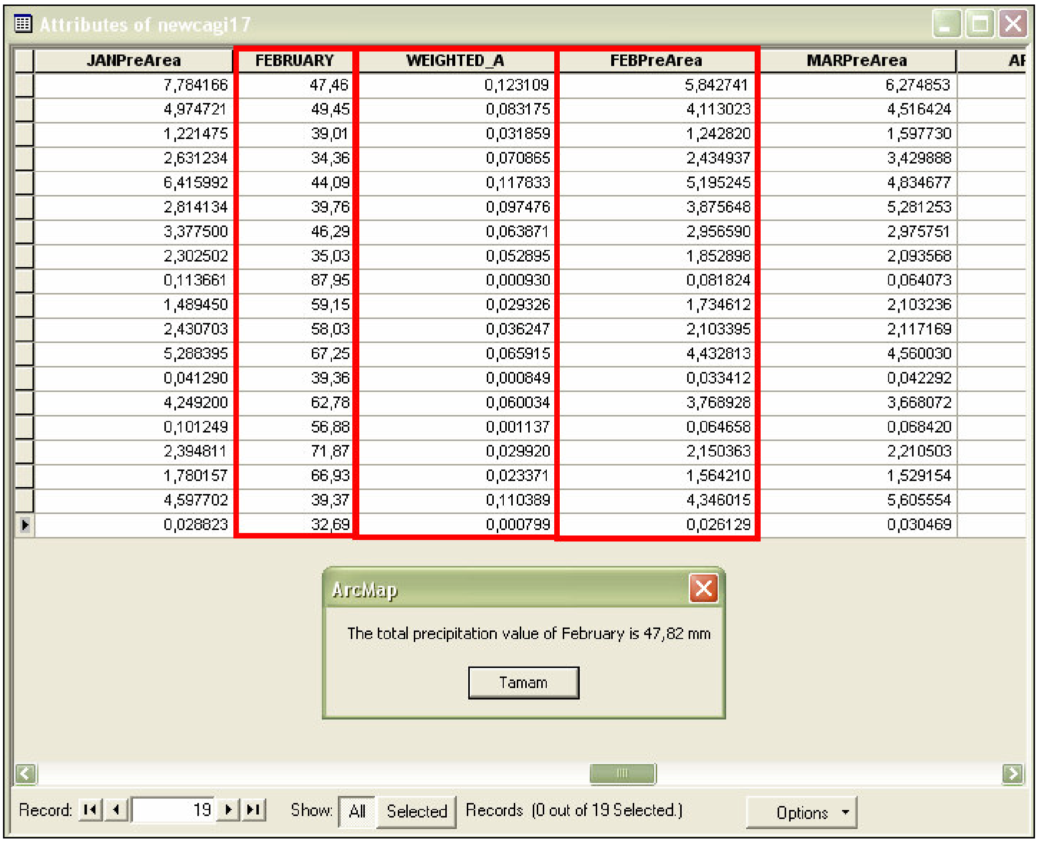


Figure 3.10 Context menu of a feature layer.

Written program automatically multiplies the weighted areas of the polygons and precipitation values of selected time interval in a basin and sum these values to find the corresponding average precipitation, which is shown in message box on the screen. A new field is then added automatically in the attribute table of the special clipped layer, as shown in Figure 3.11.



JANPreArea	FEBRUARY	WEIGHTED_A	FEBPreArea	MARPreArea
7,784166	47,46	0,123109	5,842741	6,274853
4,974721	49,45	0,083175	4,113023	4,516424
1,221475	39,01	0,031859	1,242820	1,597730
2,631234	34,36	0,070865	2,434937	3,429888
6,415992	44,09	0,117833	5,195245	4,834677
2,814134	39,76	0,097476	3,875648	5,281253
3,377500	46,29	0,063871	2,956590	2,975751
2,302502	35,03	0,052895	1,852898	2,093568
0,113661	87,95	0,000930	0,081824	0,064073
1,489450	59,15	0,029326	1,734612	2,103236
2,430703	58,03	0,036247	2,103395	2,117169
5,288395	67,25	0,065915	4,432813	4,560030
0,041290	39,36	0,000849	0,033412	0,042292
4,249200	62,78	0,060034	3,768928	3,668072
0,101249	56,88	0,001137	0,064658	0,068420
2,394811	71,87	0,029920	2,150363	2,210503
1,780157	66,93	0,023371	1,564210	1,529154
4,597702	39,37	0,110389	4,346015	5,605554
0,028823	32,69	0,000799	0,026129	0,030469

Figure 3.11 Forming new field and resulting message, which shows areal average precipitation of selected month.

Every SGS has 12 monthly, four seasonal and one annual average discharge values in the attribute table of watershed layer. If user selects any time interval and SGS name from their related comboboxes, a message will be seen on the screen. The average discharge, total precipitation and runoff coefficient are seen on the screen for the selected time interval. The same message box shows also the values of 16 basin parameters of the drainage area of selected SGS. It is shown in Figure 3.12. The clicking on OK button, the detailed map zooms to the selected basin.

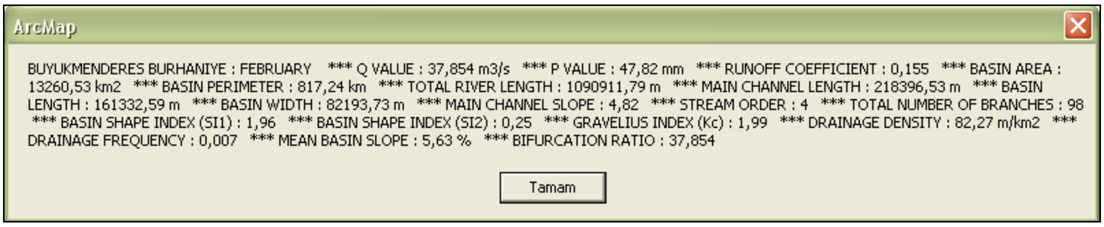


Figure 3.12 Message box of the selected basin for selected time interval.

3.12 Basin Parameters

"**Drainage basin area (A)** is in many respects the easiest basin characteristic to relate to drainage basin process but as it is in turn correlated with other characteristics, and its significance may not always be easy to interpret" (Apaydın et al., 2006). It is the most important parameter for the discharge.

Delineated basin boundaries are in polygon feature format. The length of the basin boundary is called the **perimeter (P)**. Basin area and perimeter are determined easily by using table operation menu of XTools Pro extension menu of ArcGIS software.

Total river length (TRL) is also an important basin parameter because it is related with the basin area due to water potential. For calculating total river length, all the basins layers and the drainage lines layer are clipped one by one. Resulting features are the drainage lines within each basin. Their summation gives the total river length in a basin.

The longest branch of the river is called the main branch. Its length gives **the main channel length (MCL)**. For calculating main channel length, first of all main channels for all the basins are defined. If the drainage area of the basin is very small, its main channel is formed by only one segment of drainage line, and its length gives the main channel length. But if the main channel is formed by joining some drainage line segments, then their summation gives the main channel length.

When the longest branch is continued till the boundary, the birds eye view distance between this point and the basin outlet is called **basin length**. It is denoted as L_h.

The basin width (W_h) is the ratio of the basin area to basin length. It is given by the following formula.

$$W_h = A / L_h \qquad (3.3)$$

In this study, **the main channel slope (MCS)** is calculated using the elevation values of starting point of the river, outlet point and the main channel length. Upstream elevation is taken at the water head where the main channel is starting from. The elevations of these points are found by info tool that shows elevation values by selecting the cell in the DEM. Then the slope is found as follows:

$$MCS = (h_{start} - h_{outlet}) / L \qquad (3.4)$$

Where, h_{start} and h_{outlet} are elevations at the starting point and at the outlet of the main river (m), and L is main river length (m)

Stream Order (SO) : In this study, Strahler method is used for ordering the streams. In this method, a stream, which takes no other branch but only overland flow, is called a first order stream. The second order stream is made by joining two first-order streams. When two second orders are joined, they make up a third order stream, and so on. The order of the basin is equal to the order of the main stream at the outlet. Stream order is sensitive to map scale. If two different basins are compared with each other for stream order, the map scale should be specified carefully.

The basin shape is one of the most important topographic characteristics. The shape of the basin has a major impact on the hydrograph shape and on the peak flow rate. There are some indices about the basin shape whether it is close to a circle or a square etc.

$$SI1 = L_h / W_h \qquad (3.5)$$

$$SI2 = A/A_d = 4\pi A/P^2 \qquad (3.6)$$

$$K_c = 0,28P/A^{1/2} \qquad (3.7)$$

Where: SI1, SI2: Shape indices, K_c: Gravelius index, P: Basin parameter (km), A: Basin area (km^2) and A_d : Area of the circle with the same perimeter (km^2).

Drainage density (Dd) the total length of all branches (m) in the basin divided by basin area defines the drainage density. It shows how the basin is drained.

$$Dd = TRL / A \tag{3.8}$$

Where Dd is the drainage density in m/km^2, TRL is the total river length in m and A is the basin area in km^2.

Drainage frequency (Df) is a similar term as drainage density. It gives similar information with number of branches. It is defined as the total number of branches (TNB) from all orders per unit area.

$$Df = TNB / A \tag{3.9}$$

The basin slope (S) is an important factor in surface water process. It is a significant parameter, especially in small basins where the surface flow may be a dominant factor in determining hydrograph shape. If the slope of the basin is high then the rainfall becomes surface runoff quickly. It is calculated by taking averages of each cell slope in the basin. GIS tools calculate automatically average slopes for basins in degrees and in percentages. In this study, the average slope values of the sub-basins are calculated in percentage by surface analysis tools of spatial Analyst extortion of ArcGIS software.

Bifurcation ratio (Rb) gives some idea about the basin shape and hydrograph shape at the outlet. It is given as:

$$Rb = N_u / N_{u+1} \tag{3.10}$$

Where N_u and N_{u+1} are the number of stream branches in orders u and u+1 respectively. The ratio is calculated by dividing the number of first order streams by the number of second order streams, then dividing the second order streams by the next highest order and so on. The average of all Rb ratios gives the bifurcation ratio of the basin (Usul, 2001).

The basin parameters of all sub-basins in the study area are extracted by GIS techniques and given in Table 3.2.

Table 3. 2 Extracted basin parameters for all sub-basins in the study area.

BASIN NAME	A (km^2)	P (km)	TRL (m)	MCL (m)	L_h (m)	W_h (m)	MCS	SO	TNB	SI1	SI2	K_c	Dd (m/km^2)	Df	S (%)	Rb
GAZLIGOL	225.58	102.89	15735.89	13208.87	18749.58	12031.36	2.88	2	3	1.56	0.27	1.92	69.76	0.013	2.03	2
AFYON	1591.82	282.49	124636.79	58789.59	50015.33	31826.57	2.57	3	15	1.57	0.25	1.98	78.30	0.009	3.56	3.67
GOKTEPE	250.52	77.60	12188.04	10343.22	13637.47	18370.25	32.10	2	3	0.74	0.52	1.37	48.65	0.012	8.34	2
CALIKOY	1102.41	182.47	82010.96	39842.11	35324.50	31208.13	3.56	2	10	1.13	0.42	1.54	74.39	0.009	6.72	1.5
DEGIRMENALANI	864.53	174.58	58622.45	34144.41	35154.05	24592.66	10.72	2	9	1.43	0.36	1.66	67.81	0.010	8.06	1.25
YEMISENDERE	127.26	61.77	6510.30	6510.30	12704.46	10016.59	40.09	1	1	1.27	0.42	1.53	51.16	0.008	9.60	1
AMASYA	3614.08	363.56	286924.18	97102.83	61921.38	58365.57	9.02	3	36	1.06	0.34	1.69	79.39	0.010	7.69	1.78
ALARAHAN	909.51	230.90	86913.78	60840.74	56360.94	16137.22	17.92	2	7	3.49	0.21	2.14	95.56	0.008	16.59	1.33
YAGCILI	95.67	58.33	3591.40	3591.40	11486.29	8329.23	20.88	1	1	1.38	0.35	1.67	37.54	0.010	4.97	1
EGRIGOL	2997.04	366.16	281169.91	94400.91	66158.21	45301.08	3.22	3	29	1.46	0.28	1.87	93.82	0.010	5.41	2.08
AZIZLER	1295.29	204.13	96775.88	49645.56	52880.08	24494.85	5.12	2	11	2.16	0.39	1.59	74.71	0.008	4.87	1.2
CATALLAR	2097.52	297.76	159811.39	58845.60	53276.96	39370.08	16.77	3	17	1.35	0.30	1.82	76.19	0.008	12.03	1.74
CITAK KOPRUSU	4282.54	426.77	341427.06	98202.34	82776.30	51736.35	3.64	3	24	1.60	0.30	1.83	79.73	0.006	6.02	1.81
GUNEY	10165.78	679.93	839523.39	173857.26	129269.39	78640.27	5.26	4	70	1.64	0.28	1.89	82.58	0.007	4.88	2.49
AKHAN	227.68	84.08	20263.28	20263.28	22069.71	10316.36	27.78	1	1	2.14	0.40	1.56	89.00	0.004	12.37	1
BURHANIYE	13260.53	817.24	1090911.79	218396.53	161332.59	82193.73	4.82	4	98	1.96	0.25	1.99	82.27	0.007	5.63	1.95
AYDIN KOPRUSU	20333.40	1204.70	1652853.29	312564.36	242371.69	83893.48	3.70	4	159	2.89	0.18	2.37	81.29	0.008	6.67	1.74
KAYIRLI	1134.02	222.97	88750.84	48825.92	39736.92	28538.16	6.21	2	11	1.39	0.29	1.85	78.26	0.010	7.96	1.2
CAKIRBEYLI	2981.99	391.47	235892.05	101177.46	85329.68	34946.68	6.37	3	24	2.44	0.24	2.01	79.11	0.008	7.86	1.81
SUCATI	3795.03	476.99	298297.28	130633.94	79658.63	47641.20	6.09	3	27	1.67	0.21	2.17	78.60	0.007	7.91	1.59
AKKOPRU	4908.83	474.13	408673.21	157556.01	91084.65	53893.06	7.88	3	40	1.69	0.27	1.89	83.25	0.008	8.61	1.61
TOPUZ DAMLARI	758.62	158.42	70854.00	52553.48	50926.78	14896.28	7.80	2	7	3.42	0.38	1.61	93.40	0.009	5.70	1.33
BORLU KOPRUSU	772.14	162.66	60311.78	42419.30	43082.20	17922.54	11.79	2	7	2.40	0.37	1.64	78.11	0.009	6.94	1.33
DERELI	1242.65	196.83	82440.75	45682.35	40036.37	31037.94	7.86	2	9	1.29	0.40	1.56	66.34	0.007	6.64	1.25
KAVAKLIDERE	515.65	157.21	39220.89	31164.80	29835.57	17283.11	10.75	2	5	1.73	0.26	1.94	76.06	0.010	9.03	1.5
KAYADIBI	270.54	85.15	18208.25	17086.25	20177.88	13407.70	43.66	2	3	1.50	0.47	1.45	67.30	0.011	12.65	2

Table 3. 2 (cont'd) Extracted basin parameters for all sub-basins in the study area.

BASIN NAME	A (km^2)	P (km)	TRL (m)	MCL (m)	L_h (m)	W_h (m)	MCS	SO	TNB	SI1	SI2	K_c	Dd (m/km^2)	Df	S (%)	Rb
KINIK	2450.54	351.16	188188.17	99976.71	83111.50	29484.98	14.25	3	22	2.82	0.25	1.99	76.79	0.009	11.54	2.02
SAZKOY	175.62	79.91	17145.87	17145.87	19846.48	8849.02	24.67	1	1	2.24	0.35	1.69	97.63	0.006	11.48	1.00
ACISU	3423.89	445.87	288281.91	119239.16	96908.70	35331.08	7.11	3	29	2.74	0.22	2.13	84.20	0.008	5.44	2.00
YIGITLER	72.08	49.32	2774.39	2774.39	16619.05	4337.17	72.09	1	1	3.83	0.37	1.63	38.49	0.014	10.80	1.00
DEREKOY	696.31	175.18	48758.30	48758.30	48539.71	14345.22	9.60	1	1	3.38	0.29	1.86	70.02	0.001	5.60	1.00
MANISA KOPRUSU	11755.35	958.13	987645.45	254025.11	204050.50	57610.01	4.61	4	98	3.54	0.16	2.47	84.02	0.008	6.38	1.83
DARIBUKU	1476.90	237.02	122821.26	73201.23	63571.48	23232.18	7.43	2	7	2.74	0.33	1.73	83.16	0.005	5.58	1.33
INBOGAZI	163.52	72.61	8293.88	8293.88	11483.54	14239.10	19.65	1	1	0.81	0.39	1.59	50.72	0.006	6.07	1.00
ASLAN KOPRUSU	1604.73	245.01	111989.63	58293.85	55613.07	28855.34	4.70	3	15	1.93	0.34	1.71	69.79	0.009	5.20	1.71
BUYUKBOSTANCI	966.83	213.20	86056.16	36270.64	33999.18	28436.76	6.15	3	9	1.20	0.27	1.92	89.01	0.009	4.30	2.34
BALIKLI	1188.73	207.03	101758.09	49048.40	40867.26	29087.48	4.73	3	11	1.40	0.35	1.68	85.60	0.009	3.98	1.75
SELCUK	3996.48	490.66	374013.54	117673.01	94125.43	42459.13	3.78	3	39	2.22	0.21	2.17	93.59	0.010	7.37	4.84
KAYACA	2428.53	377.39	212034.43	108542.59	98010.31	24778.33	3.21	3	22	3.96	0.21	2.14	87.31	0.009	4.72	2.75
GECITKOY	1299.38	219.94	93740.36	65441.89	45540.34	28532.53	15.25	2	3	1.60	0.34	1.71	72.14	0.002	10.01	2.00
BESKONAK	1846.46	319.85	146123.65	101071.13	79633.49	23186.97	17.82	2	11	3.43	0.23	2.08	79.14	0.006	12.74	1.20
KAYALIOGLU	801.77	177.60	51146.68	39109.11	38941.38	20589.12	10.23	2	7	1.89	0.32	1.76	63.79	0.009	5.97	1.33
KILLIK	3167.26	406.67	263773.42	111045.16	81227.87	38992.33	2.49	3	23	2.08	0.24	2.02	83.28	0.007	5.32	2.92
SINANHOCA	1278.67	249.47	104945.40	43967.25	28260.44	45246.11	16.76	3	11	0.62	0.26	1.95	82.07	0.009	10.77	2.75
SELALE	1995.90	299.93	169599.08	75193.31	49687.70	40168.80	19.76	3	17	1.24	0.28	1.88	84.97	0.009	10.80	1.74
KUCUKILET	1672.28	259.60	123300.61	74944.71	65474.88	25540.71	4.58	2	13	2.56	0.31	1.78	73.73	0.008	4.15	1.17
DOLLUK	9687.12	625.81	774754.11	209960.25	137622.63	70389.01	5.24	4	79	1.96	0.31	1.78	79.98	0.008	6.31	5.79
YAHYAKOY	6372.36	629.20	594704.31	199258.86	130062.57	48994.55	4.04	3	47	2.65	0.20	2.21	93.33	0.007	6.30	1.58

CHAPTER 4

DETERMINATION OF THE SIGNIFICANT BASIN PARAMETER(S) FOR THE ESTIMATION OF RUNOFF COEFFICIENT

In this study, the effect of basin parameters on the runoff coefficient is searched by using stepwise regression analysis.

Before starting the regression analysis, it is necessary to investigate which kind of relation is there between the dependent and independent variables, where the response (dependent variable) is runoff coefficient. The predictors (independent variables) are the basin parameters such as area, perimeter, total river length, main channel length, etc. Relationship between response and predictors can be linear or non-linear. Pekpınarlı (2005) explained that there is an exponential relation between the discharge and basin parameters and this relation was determined from previous studies. İçağa (2004) studied to find out multiple linear regression models, which are explained monthly average runoff of Akarçay Basin by total monthly rainfall, monthly average evaporation and temperature data. For this purpose, firstly all the data are normalized by Box-Cox transformation, and then they are used in linear regression analyses.

Normal distribution, which is also called Gaussian distribution, is the most widely used distribution in natural events. Hydrologic data generally do not fit the normal distribution. Furthermore, the range of the variable is from minus infinity to plus infinity in the normal distribution. But hydrologic variables generally have positive values. Their distributions are mostly skewed to the right. In spite of that, sometimes an assumption is made about the hydrologic variables to be normally distributed and sometimes variables are transformed to their logarithms, so they fit the normal distribution. If the logarithm (10 based or natural) of any variable fits the normal distribution, the distribution of this variable is lognormal. This distribution is widely used in statistical analysis of hydrologic variables. Because, these variables have positive values, and their distributions are skewed to right (Bayazıt, 1995).

It is easy to calculate the coefficients of the predictors using linear equation in regression analysis. There is an assumption on regression analysis, about the linearity between response and predictor(s). “Use of the regression equation requires that the underlying relationship be linear” (Witte and Witte, 2004).

One way to convert the exponential non-linear equation to linear form is taking logarithms on both sides of Equation 4.1. Logarithmic regression equation (Equation 4.2) turns to linear regression equation as in Equation 4.3.

$$Y=bX^n \tag{4.1}$$

$$\log Y=\log b + n\log X \tag{4.2}$$

$$Y_a=b_a + nX_a \tag{4.3}$$

The data are normalized by Box-Cox transformation and linear regression analyses are made by these normalized data.

4.1 Box-Cox Transformation

Box-Cox transformation is used to select the optimal transformation for correcting nonnormality in the data. λ (lambda) is a number that represents the “optimal” transformation for correcting nonnormality. First, the Box-Cox transformation command is used to find the optimal value of λ. The value of the pooled standard deviation for each competing value of λ is plotted in the Box-Cox plot.

The Box-Cox plot includes:

1. A plot of each possible value for λ vs the pooled standard deviation that results from each transformation.
2. An optimal and the rounded value for λ.
3. A 95% confidence interval for λ which is contained within the red lines on a plot.
4. When the confidence interval for λ includes 1.0, no transformation of the data is needed.
5. When the confidence interval for λ does not include 1.0, a transformation should be considered.

$Y'=Y^{\lambda}$ when λ is not equal to 0. $Y'=\log_e Y$ when λ=0. If λ=0.5, a square root transformation should be used in order to correct nonnormality in the data. The criteria for determining the optimal value of λ is to find the one that minimizes the pooled standard deviation of the data. Table 4.1 shows the common values for λ.

Table 4. 1 Common values for λ.

λ	Y'
2	Y^2
0.5	$Y^{0.5}$
0	$\log_e Y$
-0.5	$1/(Y^{0.5})$
-1	1/Y

The best transformation in a practical sense would be to use the rounded estimate of λ (Minitab Software). In Figure 4.1, an example is given for Box-Cox plot of K_c (Gravelius index) parameter which is used in this study.

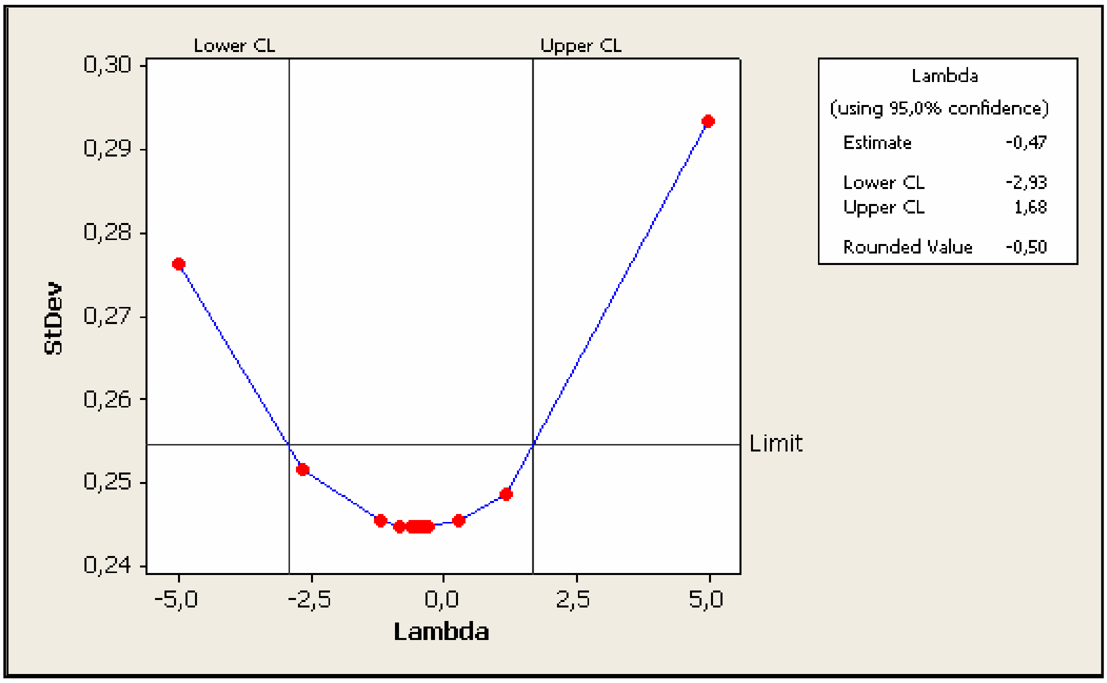


Figure 4. 1 Box-Cox plot for the K_c data.

For the K_c data, the optimal value for λ is -0.47 and the rounded value is -0.50. This corresponds to a transformation of $1/(Y^{0.5})$. Confidence bounds for λ are also included in this figure. The confidence interval ranges from -2.93 to 1.68. λ values for the data of responses (such as monthly and annual runoff coefficients) and predictors (as mentioned before, some basin parameters) are shown in Table 4.2.

Table 4. 2 λ values for responses and predictors data.

Variable	**λ**	**Variable**	**λ**	**Variable**	**λ**	**Variable**	**λ**	**Variable**	**λ**
P (km)	0.50	SO	1.00	S (%)	-0.50	Jun. C	-0.50	Ann. C	0.00
A (km^2)	0.00	TNB	0.00	Rb	-0.50	Jul. C	0.00	Fall. C	0.00
TRL (m)	0.21	SI1	0.00	Jan. C	0.00	Aug. C	0.50	Sum. C	0.00
MCL (m)	0.50	SI2	0.00	Feb. C	0.00	Sep. C	0.50	Spr. C	0.00
L_h (m)	0.50	K_c	-0.50	Mar. C	0.50	Oct. C	0.00	Win. C	0.00
W_h (m)	0.50	Dd(m/km^2)	3.00	Apr. C	0.00	Nov. C	0.00		
MCS	-0.50	Df	1.00	May. C	-0.50	Dec. C	0.00		

The descriptive statistics of the data for before and after the Box-Cox transformation are given in Table 4.3 and Table 4.4.

4.2 Correlations between the Predictors

The range for correlation coefficient is from minus one to plus one. It explains two things about the linear relationship between two variables. These are strength and the direction of the relationship. If the absolute value of the coefficient is larger, the linear relationship between the variables is the stronger. An absolute value of one indicates a perfect linear relationship. Zero value indicates absence of a linear relationship. An intermediate value is interpreted as a weak, moderate or strong correlation depending on the objectives and requirements. The sign of the coefficient indicates the direction of the relationship. A positive coefficient means both variables tend to increase or decrease together. If the coefficient is negative that means one variable tends to increase as the other decreases. The correlation does not imply causality. It is also noted in here that the correlation coefficient only measures linear relationships. If the correlation coefficient is zero, a meaningful non-linear relationship may exist between the variables (Minitab Software).

The correlation between the independent variables should be investigated. It is important to make regression analysis with predictors which do not have much correlation among them. The correlation matrix of the 16 basin parameters is shown in Table 4.5.

Table 4. 3 Descriptive statistics of the data before Box-Cox transformation for 48 sub-basins.

Variable	Total Count	N	N*	Mean	SE Mean	StDev	Variance	Sum	Sum of Squares	Minimum	Median	Maximum	Range	Skewness	Kurtosis
P (km)	48	48	0	313,2	34,5	239	57137,9	15031,7	7392840,6	49,3	241	1204,7	1155,4	1,76	3,79
A (km^2)	48	48	0	2882	573	3973	15780797	138341	1140412583	72	1388	20333	20261	2,69	8,1
TRL (m)	48	48	0	236133	47417	328516	1,08E+11	11334368	7,75E+12	2774	108468	1652853	1650079	2,6	7,49
MCL (m)	48	48	0	81060	9924	68752	4,73E+09	3890884	5,38E+11	2774	58818	312564	309790	1,47	2,18
L_h (m)	48	48	0	64762	7004	48522	2,35E+09	3108555	3,12E+11	11484	51903	242372	230888	1,74	3,71
W_h (m)	48	48	0	32689	2835	19639	3,86E+08	1569076	69419081932	4337	28697	83893	79556	1	0,61
MCS	48	48	0	0,01243	0,00188	0,01301	0,00017	0,59661	0,01537	0,00249	0,00762	0,07209	0,06959	2,69	9,09
SO	48	48	0	2,458	0,126	0,874	0,764	118	326	1	2,5	4	3	-0,07	-0,62
TNB	48	48	0	22,79	4,46	30,89	954,04	1094	69774	1	11	159	158	2,67	8,13
SI1	48	48	0	2,026	0,123	0,849	0,721	97,227	230,812	0,625	1,809	3,955	3,331	0,65	-0,4
SI2	48	48	0	0,3046	0,0112	0,0779	0,0061	14,6223	4,7394	0,1609	0,2911	0,5228	0,3619	0,5	0,08
K_c	48	48	0	1,8424	0,0346	0,2396	0,0574	88,4341	165,6263	1,3727	1,8399	2,4744	1,1016	0,44	-0,06
Dd (m/km^2)	48	48	0	76,78	1,95	13,54	183,44	3685,34	291574,72	37,54	79,12	97,63	60,09	-1,22	1,69
Df ($\#/km^2$)	48	48	0	0,008269	0,00033	0,0023	0,000005	0,396898	0,00353	0,001436	0,00848	0,013874	0,01244	-0,51	1,92
S (%)	48	48	0	7,491	0,429	2,969	8,815	359,586	3108,078	2,03	6,655	16,59	14,56	0,87	0,57
Rb	48	48	0	1,838	0,134	0,931	0,867	88,202	202,831	1	1,725	5,79	4,79	2,52	7,87
Jan. C	48	46	2	0,316	0,0301	0,204	0,0416	14,5346	6,4659	0,0551	0,2831	0,9591	0,9041	1,16	1,49
Feb. C	48	44	4	0,3915	0,0317	0,2105	0,0443	17,2278	8,6502	0,0925	0,3739	0,9873	0,8948	0,59	-0,05
Mar. C	48	43	5	0,3539	0,0304	0,1991	0,0396	15,2187	7,0512	0,0841	0,3073	0,8185	0,7344	0,51	-0,63
Apr. C	48	41	7	0,35	0,0332	0,2124	0,0451	14,3511	6,828	0,1041	0,2724	0,9473	0,8432	1,21	1,26
May. C	48	40	8	0,2437	0,024	0,152	0,0231	9,748	3,2768	0,0784	0,1962	0,7511	0,6727	1,63	2,6
Jun. C	48	41	7	0,2616	0,0285	0,1824	0,0333	10,7269	4,1372	0,0624	0,1979	0,9103	0,8479	2,09	4,73
Jul. C	48	41	7	0,2949	0,0382	0,2443	0,0597	12,0926	5,9538	0,0182	0,2568	0,8691	0,8509	0,75	-0,54
Aug. C	48	37	11	0,2715	0,0401	0,2437	0,0594	10,0456	4,8661	0,0061	0,2365	0,9192	0,9131	0,85	-0,03
Sep. C	48	41	7	0,184	0,0276	0,1767	0,0312	7,5436	2,6363	0,0036	0,1425	0,6762	0,6726	1,19	0,69
Oct. C	48	47	1	0,1347	0,0256	0,1756	0,0308	6,331	2,2715	0,0134	0,083	0,7444	0,731	2,57	6,05
Nov. C	48	47	1	0,1289	0,0211	0,1449	0,021	6,0588	1,7466	0,0131	0,0675	0,6717	0,6586	2,3	5,17
Dec. C	48	47	1	0,2283	0,0289	0,1984	0,0394	10,7305	4,2602	0,0444	0,1585	0,8778	0,8334	1,81	3,38
Fall C	48	47	1	0,1541	0,0276	0,1889	0,0357	7,2417	2,7578	0,012	0,0978	0,8704	0,8584	2,51	6,2
Win.C	48	45	3	0,2885	0,0268	0,1796	0,0322	12,9824	5,1641	0,0616	0,2539	0,8919	0,8302	1,13	1,74
Spr. C	48	42	6	0,3378	0,0332	0,2155	0,0464	14,1873	6,6961	0,0962	0,2603	0,9498	0,8535	1,24	1,18
Sum. C	48	41	7	0,2922	0,0348	0,2231	0,0498	11,9821	5,4933	0,0432	0,2474	0,9117	0,8684	1,19	0,79
Ann. C	48	44	4	0,2732	0,027	0,1793	0,0322	12,0196	4,6663	0,0766	0,1969	0,9461	0,8695	1,78	3,92

Table 4. 4 Descriptive statistics of the data after Box-Cox transformation.

Variable	Total Count	N	N*	Mean	SE Mean	StDev	Variance	Sum	Sum of Squares	Minimum	Median	Maximum	Range	Skewness	Kurtosis
P (km)	48	48	0	16,61	0,891	6,17	38,075	797,262	15031,743	7,023	15,524	34,709	27,686	0,77	0,69
A (km^2)	48	48	0	7,218	0,191	1,324	1,753	346,446	2582,892	4,278	7,234	9,92	5,642	-0,26	-0,21
TRL (m)	48	48	0	11,164	0,457	3,169	10,04	535,873	6454,381	5,098	10,824	18,944	13,846	0,28	-0,03
MCL (m)	48	48	0	260,3	16,8	116,7	13612,5	12492,1	3890883,7	52,7	242,5	559,1	506,4	0,44	0,02
L_h (m)	48	48	0	239,4	12,6	87,3	7623,1	11489,7	3108555,1	107,2	227,8	492,3	385,2	0,76	0,69
W_h (m)	48	48	0	172,95	7,69	53,25	2835,81	8301,69	1569076,37	65,86	169,4	289,64	223,79	0,34	-0,28
MCS	48	48	0	11,6	0,615	4,263	18,176	556,822	7313,645	3,725	11,461	20,022	16,298	0,1	-0,91
SO	48	48	0	2,458	0,126	0,874	0,764	118	326	1	2,5	4	3	-0,07	-0,62
TNB	48	48	0	2,367	0,195	1,349	1,82	113,612	354,441	0	2,398	5,069	5,069	-0,28	-0,44
SI1	48	48	0	0,6179	0,0624	0,4322	0,1868	29,6599	27,1084	-0,4707	0,5916	1,3751	1,8458	-0,25	-0,15
SI2	48	48	0	-1,2207	0,0372	0,2575	0,0663	-58,5942	74,6434	-1,8269	-1,2343	-0,6485	1,1784	-0,13	-0,32
K_c	48	48	0	0,74124	0,00686	0,04756	0,00226	35,57964	26,47944	0,63572	0,73724	0,85351	0,21778	0,03	-0,34
Dd (m/km^2)	48	48	0	491124	29994	207806	4,32E+10	23573938	1,36E+13	52898	495316	930557	877659	-0,11	-0,03
Df (#/km^2)	48	48	0	0,008269	0,00033	0,0023	0,000005	0,396898	0,00353	0,001436	0,00848	0,013874	0,01244	-0,51	1,92
S (%)	48	48	0	0,3871	0,0117	0,0808	0,0065	18,582	7,5002	0,2455	0,3876	0,7019	0,4563	1,16	3,57
Rb	48	48	0	0,7852	0,0208	0,1439	0,0207	37,6883	30,565	0,4156	0,7614	1	0,5844	-0,38	0,01
Jan. C	48	46	2	-1,364	0,101	0,687	0,473	-62,764	106,905	-2,899	-1,262	-0,042	2,857	-0,3	-0,56
Feb. C	48	44	4	-1,0996	0,0916	0,6075	0,369	-48,3816	69,067	-2,3801	-0,9843	-0,0127	2,3674	-0,46	-0,67
Mar. C	48	43	5	0,5703	0,0261	0,1713	0,0293	24,524	15,2187	0,29	0,5544	0,9047	0,6147	0,06	-0,96
Apr. C	48	41	7	-1,2198	0,0928	0,5944	0,3533	-50,0123	75,1387	-2,2624	-1,3005	-0,0541	2,2082	0,05	-0,77
May. C	48	40	8	2,2694	0,0945	0,5977	0,3573	90,7762	219,9408	1,1538	2,2575	3,5704	2,4166	0,23	-0,3
Jun. C	48	41	7	2,2186	0,0949	0,6076	0,3692	90,9636	216,5829	1,0481	2,2478	4,0035	2,9553	0,4	0,78
Jul. C	48	41	7	-1,686	0,172	1,103	1,216	-69,143	165,236	-4,008	-1,359	-0,14	3,868	-0,51	-0,85
Aug. C	48	37	11	0,4595	0,0409	0,249	0,062	17,0031	10,0456	0,0781	0,4863	0,9587	0,8806	0,14	-1,12
Sep. C	48	41	7	0,3773	0,0323	0,2065	0,0427	15,4701	7,5436	0,0597	0,3774	0,8223	0,7626	0,37	-0,72
Oct. C	48	47	1	-2,528	0,142	0,975	0,95	-118,836	344,178	-4,316	-2,489	-0,295	4,021	0,53	0,05
Nov. C	48	47	1	-2,473	0,129	0,882	0,778	-116,229	323,218	-4,333	-2,695	-0,398	3,935	0,54	0,03
Dec. C	48	47	1	-1,801	0,12	0,821	0,674	-84,669	183,543	-3,114	-1,842	-0,13	2,984	0,09	-0,78
Fall C	48	47	1	-2,348	0,137	0,936	0,877	-110,368	299,501	-4,423	-2,324	-0,139	4,284	0,48	0,21
Win.C	48	45	3	-1,4403	0,0984	0,66	0,4357	-64,8132	112,5188	-2,7863	-1,3707	-0,1144	2,6719	-0,26	-0,71
Spr. C	48	42	6	-1,2714	0,0957	0,6201	0,3846	-53,3973	83,6549	-2,3408	-1,3458	-0,0515	2,2893	0,08	-0,77
Sum. C	48	41	7	-1,519	0,124	0,794	0,63	-62,274	119,804	-3,141	-1,397	-0,092	3,048	-0,08	-0,89
Ann. C	48	44	4	-1,4708	0,0876	0,5808	0,3374	-64,7139	109,6861	-2,5698	-1,6257	-0,0554	2,5144	0,36	-0,39

Table 4. 5 The correlation matrix of the data of predictors which were transformed by Box-Cox transformation.

	P (km)	A (km^2)	TRL (m)	MCL (m)	L_h (m)	W_h (m)	MCS	SO	TNB	SI1	SI2	K_c	Dd (m/km^2)	Df	S (%)	Rb
P (km)	1.00	0.96	0.99	0.98	0.97	0.91	0.56	0.88	0.93	0.29	-0.76	-0.75	0.46	-0.18	0.08	-0.54
A (km^2)	0.96	1.00	0.99	0.97	0.93	0.94	0.60	0.90	0.96	0.22	-0.66	-0.66	0.50	-0.22	0.09	-0.59
TRL (m)	0.99	0.99	1.00	0.98	0.96	0.94	0.59	0.90	0.95	0.25	-0.69	-0.69	0.52	-0.21	0.09	-0.57
MCL (m)	0.98	0.97	0.98	1.00	0.98	0.88	0.55	0.85	0.91	0.37	-0.72	-0.72	0.51	-0.26	0.05	-0.51
L_h (m)	0.97	0.93	0.96	0.98	1.00	0.82	0.55	0.81	0.89	0.47	-0.73	-0.73	0.47	-0.22	0.08	-0.47
W_h (m)	0.91	0.94	0.94	0.88	0.82	1.00	0.53	0.91	0.92	-0.08	-0.53	-0.53	0.36	-0.14	0.08	-0.61
MCS	0.56	0.60	0.59	0.55	0.55	0.53	1.00	0.58	0.62	0.15	-0.48	-0.48	0.37	0.05	0.70	-0.54
SO	0.88	0.90	0.90	0.85	0.81	0.91	0.58	1.00	0.94	0.04	-0.61	-0.61	0.42	0.08	0.18	-0.78
TNB	0.93	0.96	0.95	0.91	0.89	0.92	0.62	0.94	1.00	0.16	-0.64	-0.64	0.46	0.05	0.13	-0.64
SI1	0.29	0.22	0.25	0.37	0.47	-0.08	0.15	0.04	0.16	1.00	-0.45	-0.45	0.35	-0.19	-0.01	0.12
SI2	-0.76	-0.66	-0.69	-0.72	-0.73	-0.53	-0.48	-0.61	-0.64	-0.45	1.00	1.00	-0.52	0.12	-0.10	0.41
K_c	-0.75	-0.66	-0.69	-0.72	-0.73	-0.53	-0.48	-0.61	-0.64	-0.45	1.00	1.00	-0.52	0.13	-0.11	0.41
Dd (m/km^2)	0.46	0.50	0.52	0.51	0.47	0.36	0.37	0.42	0.46	0.35	-0.52	-0.52	1.00	-0.24	-0.04	-0.33
Df	-0.18	-0.22	-0.21	-0.26	-0.22	-0.14	0.05	0.08	0.05	-0.19	0.12	0.13	-0.24	1.00	0.21	-0.20
S (%)	0.08	0.09	0.09	0.05	0.08	0.08	0.70	0.18	0.13	-0.01	-0.10	-0.11	-0.04	0.21	1.00	-0.23
Rb	-0.54	-0.59	-0.57	-0.51	-0.47	-0.61	-0.54	-0.78	-0.64	0.12	0.41	0.41	-0.33	-0.20	-0.23	1.00

In this thesis, it is assumed that an absolute value of 0.6 for correlation coefficient indicates strong correlation among two predictors. Then they are not used in the same regression model. If these correlated variables are used in the same model, that can cause biases in the results.

4.3 Stepwise Regression Analysis

The stepwise regression model is based on the specified Alpha-to-Enter and Alpha-to-Remove values for the purpose of identifying a useful subset of predictors. There are commonly used procedures provided by Minitab Statistical Software, such as:

1. The procedure adds and removes variables. It is called as standard stepwise regression.
2. The procedure adds variables. It is called as forward selection.
3. The procedure removes variables. It is called as backwards elimination.

Stepwise regression analysis is applied to data which are transformed by Box-Cox transformation by considering the correlation between the predictors. An output example of stepwise regression analysis from Minitab 15 Statistical Software is shown in Table 4.6. There is a summary line at the top of the output, which includes response (dependent variable) name, the number of predictors (independent variables) considered and the number of observations used in the analysis. The terms used in the analysis are explained as follows.

1. S is the standard deviation of the error term in the model. If S is small, the model fits the data better.
2. R-Sq is the proportion that shows how the response (runoff coefficient) data is explained by the model.
3. R-Sq (adj) is a modified R-Sq. It has been adjusted for the number of terms in the model. R can be artificially high, it may include unnecessary terms in the model. But adjusted R may get smaller when terms are added to the model.
4. Mallow's_Cp explains how well the model fits the data. It should be close to the number of predictors contained in the model plus the constant.
5. PRESS equals the sum of squares of the prediction errors. If PRESS is small, the model generally predicts the data better.
6. R-sq (pred) shows how well the model will predict future data (Minitab Software).

Table 4. 6 Sample output of stepwise regression analysis**.**

Stepwise Regression: RcANN_N versus MCS_N; Rb_N; TRL(m)_N; Df_N

```
Alpha-to-Enter: 0,15  Alpha-to-Remove: 0,15

Response is RcANN_N on 4 predictors, with N = 13

Step              1        2        3
Constant    -0,4859  -2,2393  -1,3090

MCS_N        -0,099   -0,076   -0,086
T-Value       -4,81    -4,15    -5,30
P-Value       0,001    0,002    0,000

Rb_N                    1,81     1,49
T-Value                 2,79     2,60
P-Value                0,019    0,029

Df_N                               -66
T-Value                          -2,20
P-Value                          0,056

S             0,299    0,235    0,200
R-Sq          67,79    81,87    88,20
R-Sq(adj)     64,86    78,24    84,26
Mallows Cp     15,1      6,6      3,8
```

In Table 4.6, the normalized data of MCS_N (main channel slope), Rb_N (bifurcation ratio) and Df_N (drainage frequency) are used for determining the RcANN_N (annual runoff coefficient). This output is an example from Büyük Menderes Basin.

In regression analysis, t test is used to determine the significance of the parameters. The t value of the predictor is calculated as the coefficient of the predictor divided by the standard error of the coefficient. The p value is related with the calculated t value. If p probability value of the t test is smaller than selected α confidence interval, the parameter is determined as significant. If the t value is larger, the p value is smaller. Depending on the p value, the predictor is entered or removed from the model. Alpha-to-enter is the value that determines if any of the predictors, not currently in the model, should be added to the model. The p value of each predictor, which is not in the model, is compared to this model α (alpha) level. If the p value of a predictor is less than α level, it is entered into the model. The α level is between 0 and 1.0. Alpha-to-remove is the value which is also between 0 and 1.0. It determines if any of the predictors in the model should be removed from the model. The p value of each predictor in the model is compared to α level. If the p value of a predictor is greater than α level, that predictor is also a candidate to be removed from the model (Minitab Software).

At the first step, MCS_N has the smallest p value (0.001), which is less than 0.15. Thus it is the first predictor to be entered in the model. It has 64.86 % R-sq (adj) value. At the second step, Rb_N has the smallest p-value (0.019) less than 0.15, therefore it is the second predictor to be entered into the model. In this model, the coefficient of MCS_N is -0.076, the t-value is -4.15, and the p-value is 0.002. This model has 78.24% R-sq (adj) value. At the third step Df_N has the smallest p value (0.056), which is less than 0.15. So, it is the third predictor to be entered in the model. After the third step, none of predictors have p-values less than 0.15. Thus, no predictors can be entered into or removed from the model. The final model includes three predictors such as MCS_N, Rb_N and Df_N. The value of R-sq (adj) of this model is 84.26%.

CHAPTER 5

EVALUATION OF THE RESULTS

Runoff coefficients for all the sub-basins in the study area are determined for each month, each season, and also for the year. Before trying to find which parameters have effect on the runoff coefficient, coefficient itself is studies for the region, to understand how it is changing in the area and in time. This information may be important for the water potential of the region.

5.1 Evaluation of Runoff Coefficients

Monthly, seasonal and annual runoff coefficients are calculated for 48 sub-basins in western and southern part of Turkey. 14 of them have greater runoff coefficient values than 1.0 for some months, seasons and also as annual value. So these basins are not included in the average runoff coefficient calculations for the corresponding times. They are generally located in south-western and south of Turkey. Some sub-basins, which are located at the upstream parts of basins, have also greater runoff coefficient than 1.0 for some months. There may be some reasons for having runoff coefficient higher than 1.0. Firstly, groundwater may feed the streams. Secondly, areal average precipitation may not be correct because of the data some of POSs do not explain the precipitation in the sub-basins sufficiently due to the topographic conditions. Thirdly, there are some dams built for irrigation purposes in these sub-basins, which change the natural flows.

Runoff coefficients calculated as average values for the whole region are given in Table 5.1 for the months, seasons and for the year. Annual average runoff coefficient value is 0.27 for the whole study area. February coefficient is the largest as 0.39, among all months, while October and November coefficients are the smallest with a 0.13 value. The largest seasonal average runoff coefficient value is obtained from spring as 0.34, and the smallest one is obtained from fall as 0.15. Summer and winter runoff coefficients are equal to each other being 0.29 (Table 5.1).

Table 5.1 Monthly, seasonal and annual average runoff coefficients.

Month	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
C_{ave}	0.32	0.39	0.35	0.35	0.24	0.26	0.29	0.27	0.18	0.13	0.13	0.23

Season	FAL	SUM	SPR	WIN	ANN
C_{ave}	0.15	0.29	0.34	0.29	0.27

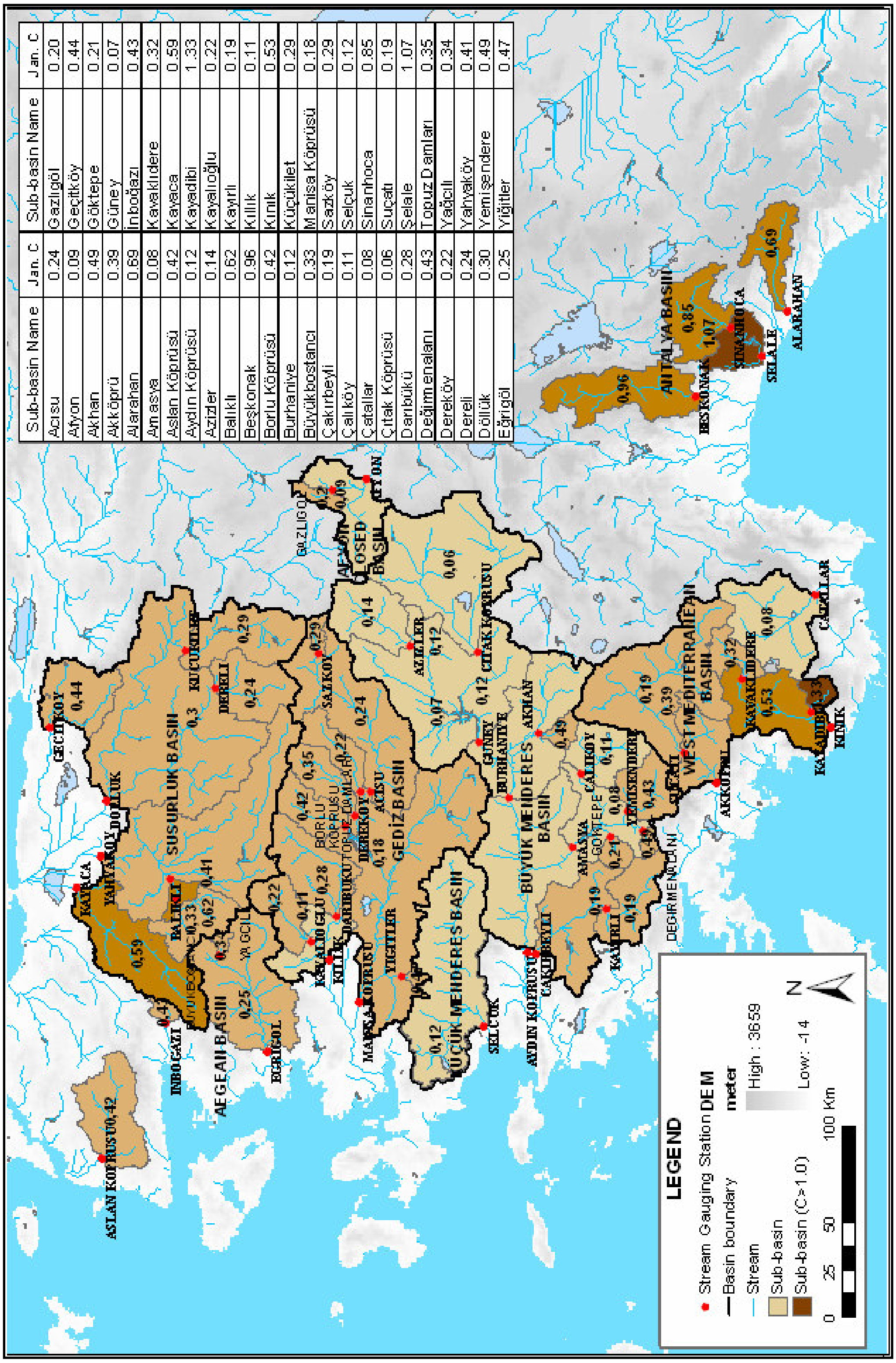
5.1.1 Monthly Runoff Coefficients

As it is seen in Table 5.1 monthly coefficients change from 0.13 to 0.39, and except February value, all the months have smaller runoff coefficient than Turkey's average value.

January average runoff coefficient value is 0.32 in the study area. Beşkonak sub-basin, which is located in Antalya Basin, has the largest value as 0.96. Sinanhoca sub-basin has also a large runoff coefficient. South part of study area has generally large runoff coefficient values. The reason could be that, this region is karstic and there are springs, which are fed from groundwater. Çıtak köprüsü sub-basin, which is located in Büyük Menderes Basin, in the east part of the study area, has the smallest runoff coefficient as 0.06. Similarly, in the same basin Güney and Amasya, and at the south, has also small runoff coefficient. Çatallar sub-basins have small runoff coefficient values (Figure 5.1).

February average runoff coefficient value is 0.39 for the region. Alarahan has the largest value with 0.99, which is also located at south part of the region. Çıtak köprüsü sub-basin has smallest value with 0.09, as in January. The other small values belong to Güney and Kıllık sub-basins, which are located east and west part of the region respectively (Figure 5.2).

Average runoff coefficient values in March and April are 0.35. Kınık, which is located at the south part of the region, has largest runoff coefficient value with 0.82, and Güney has smallest runoff coefficient value with 0.08 for March. Çalıköy, Amasya, Çıtak Köprüsü and Kıllık sub-basins have also small runoff coefficient values for the same month (Figure 5.3). Geçitköy has largest April runoff coefficient with 0.95, which is located at the north part of the region. It may be because of Uludağ which is located in that sub-basin and snowmelt starting in April has an important factor on surface flow. The other small values for April belong to Sazköy and Kıllık sub-basins, which are located in the east and west parts of the region, respectively (Figure 5.4).



Sub-basin Name	Jan. C	Sub-basin Name	Jan. C
Acısu	0.24	Gazlıgöl	0.20
Afyon	0.09	Geçitköy	0.44
Akhan	0.49	Göktepe	0.21
Akköprü	0.39	Güney	0.07
Alarahan	0.69	İnboğazı	0.43
Amasya	0.08	Kavaklıdere	0.32
Aslan Köprüsü	0.42	Kayaca	0.59
Aydın Köprüsü	0.12	Kayadibi	1.33
Azizler	0.14	Kayalıoğlu	0.22
Balıklı	0.62	Kayırlı	0.19
Beşkonak	0.96	Kıllık	0.11
Borlu Köprüsü	0.42	Kınık	0.53
Burhaniye	0.12	Küçükilet	0.29
Büyükbostancı	0.33	Manisa Köprüsü	0.18
Çakırbeyli	0.19	Sazköy	0.29
Çallıköy	0.11	Selçuk	0.12
Çatallar	0.08	Sinanhoca	0.85
Çıtak Köprüsü	0.06	Suçatı	0.19
Darıbükü	0.28	Şelale	1.07
Değirmenalanı	0.43	Topuz Damları	0.35
Dereköy	0.22	Yağcılı	0.34
Dereli	0.24	Yahyaköy	0.41
Döllük	0.30	Yemişendere	0.49
Eğrigöl	0.25	Yiğitler	0.47

Figure 5.1 Sub-basins and their January runoff coefficients in the study area.

Sub-basin Name	Feb. C	Sub-basin Name	Feb. C
Acısu	0.33	Gazlıgöl	0.39
Afyon	0.20	Geçitköy	0.61
Akhan	0.55	Göktepe	0.22
Akköprü	0.61	Güney	0.10
Alarahan	0.99	İnboğazı	0.55
Amasya	0.13	Kavaklıdere	0.61
Aslan Köprüsü	0.66	Kayaca	0.72
Aydın Köprüsü	0.16	Kayadibi	1.55
Azizler	0.26	Kayalıoğlu	0.33
Balıklı	0.65	Kayırlı	0.27
Beşkonak	1.33	Kıllık	0.13
Borlu Köprüsü	0.41	Kınık	0.70
Burhaniye	0.15	Küçükilet	0.39
Büyükbostancı	0.32	Manisa Köprüsü	0.22
Çakırbeyli	0.29	Sazköy	0.44
Çalıköy	0.13	Selçuk	0.18
Çatallar	0.12	Sinanhoca	1.22
Çıtak Köprüsü	0.09	Suçatı	0.32
Darıbükü	0.39	Şelale	1.52
Değirmenalanı	0.47	Topuz Damları	0.36
Dereköy	0.31	Yağcılı	0.40
Dereli	0.47	Yahyaköy	0.58
Döllük	0.47	Yemişendere	0.55
Eğrigöl	0.25	Yiğitler	0.76

Figure 5.2 Sub-basins and their February runoff coefficients in the study area.

Sub-basin Name	Mar. C	Sub-basin Name	Mar. C
Acısu	0.24	Gazıgöl	0.36
Afyon	0.20	Geçitköy	0.73
Akhan	0.50	Göktepe	0.32
Akköprü	0.58	Güney	0.08
Alarahan	1.25	İnboğazı	0.52
Amasya	0.10	Kavaklıdere	0.69
Aslan Köprüsü	0.48	Kayaca	0.70
Aydın Köprüsü	0.14	Kayadibi	2.17
Azizler	0.25	Kayalıoğlu	0.26
Balıklı	0.50	Kayırlı	0.26
Beşkonak	1.41	Kıllık	0.10
Borlu Köprüsü	0.31	Kınık	0.82
Burhaniye	0.13	Küçükilet	0.36
Büyükbostancı	0.26	Manisa Köprüsü	0.17
Çakırbeyli	0.26	Sazköy	0.50
Çalıköy	0.09	Selçuk	0.14
Çatallar	0.13	Sinanhoca	1.48
Çıtak Köprüsü	0.09	Suçatı	0.32
Darıbükü	0.27	Şelale	1.70
Değirmenalanı	0.49	Topuz Damları	0.30
Dereköy	0.22	Yağcılı	0.40
Dereli	0.45	Yahyaköy	0.51
Döllük	0.51	Yemişendere	0.54
Eğrigöl	0.24	Yiğitler	0.69

Figure 5.3 Sub-basins and their March runoff coefficients in the study area.

Sub-basin Name	Apr. C	Sub-basin Name	Apr. C
Acısu	0.26	Gazlıgöl	0.27
Afyon	0.18	Geçitköy	0.95
Akhan	0.57	Göktepe	0.36
Akköprü	0.71	Güney	0.11
Alarahan	2.20	İnboğazı	0.45
Amasya	0.15	Kavaklıdere	1.26
Aslan Köprüsü	0.48	Kayaca	0.54
Aydın Köprüsü	0.14	Kayadibi	4.41
Azizler	0.30	Kayalıoğlu	0.27
Balıklı	0.43	Kayırlı	0.31
Beşkonak	1.88	Kıllık	0.10
Borlu Köprüsü	0.27	Kınık	1.31
Burhaniye	0.12	Küçükilet	0.30
Büyükbostancı	0.21	Manisa Köprüsü	0.17
Çakırbeyli	0.26	Sazköy	0.93
Çalıköy	0.11	Selçuk	0.14
Çatallar	0.22	Sinanhoca	2.50
Çıtak Köprüsü	0.13	Suçatı	0.37
Darıbükü	0.27	Şelale	2.56
Değirmenalanı	0.57	Topuz Damları	0.26
Dereköy	0.19	Yağcılı	0.39
Dereli	0.45	Yahyaköy	0.46
Döllük	0.48	Yemişendere	0.50
Eğrigöl	0.22	Yiğitler	0.74

Figure 5.4 Sub-basins and their April runoff coefficients in the study area.

May average runoff coefficient value is 0.24. Kavaklıdere sub-basin has largest runoff coefficient with 0.75, which is located at the south part of the region. Afyon sub-basin has smallest runoff coefficient with 0.08, which is located at the east. Çalıköy, Güney, Aydın Köprüsü, Burhaniye, Selçuk and Büyükbostancı sub-basins have also small runoff coefficient values, which are located at the middle part of the region in north south direction (Figure 5.5).

June average runoff coefficient value is 0.26. Akhan sub-basin has largest runoff coefficient with 0.91, which is located at southeast part of study area. Geçitköy also has large runoff coefficient. Afyon sub-basin has smallest runoff coefficient with 0.06, as in May. Kıllık and Dereköy sub-basins have also small runoff coefficient values. They are located west and middle parts of the region respectively (Figure 5.6).

July average runoff coefficient value is 0.29. Yağcılı sub-basin has largest runoff coefficient with 0.87, which is located at northwest part of the region. It is upstream of Eğrigöl sub-basin in Aegean basin. Akhan sub-basin has also large runoff coefficient with 0.78, which is upstream of Burhaniye sub-basin in Büyük Menderes Basin. Afyon and İnboğazı sub- basins have smallest runoff coefficients with 0.02, at the east and northwest part of the region, respectively (Figure 5.7).

August average runoff coefficient value is 0.27. Balıklı sub-basin has largest runoff coefficient with 0.92, which is located at the northwest part of the region. Azizler, İnboğazı and Selçuk sub-basins have smallest runoff coefficient values with 0.01, as in July (Figure 5.8).

September average runoff coefficient value is 0.18. Amasya sub-basin has largest runoff coefficient value with 0.68. Selçuk sub-basin has smallest runoff coefficient value with 0.004, which is located in Küçük Menderes Basin. East, middle, west and northwest parts of the region have small runoff coefficient values (such as Borlu Köprüsü and Kayalıoğlu sub-basins) (Figure 5.9).

Average runoff coefficient values in October and November are 0.13. Beşkonak has largest runoff coefficient values as 0.74 and 0.67 for October and November, respectively. Şelale and Akhan sub-basins have also large runoff coefficient values for October, which are located in the south and southeast parts of the region. Selçuk sub-basin has smallest runoff coefficient value with 0.01 for both of them (Figures 5.10 and 5.11).

Sub-basin Name	May C	Sub-basin Name	May C
Acısu	0.22	Gazlıgöl	0.16
Afyon	0.08	Geçitköy	1.25
Akhan	0.60	Göktepe	0.24
Akköprü	0.52	Güney	0.11
Alarahan	3.52	İnboğazı	0.25
Amasya	0.16	Kavaklıdere	0.75
Aslan Köprüsü	0.33	Kayaca	0.26
Aydın Köprüsü	0.11	Kayadibi	5.40
Azizler	0.17	Kayalıoğlu	0.20
Balıklı	0.24	Kayırlı	0.19
Beşkonak	2.44	Kıllık	0.08
Borlu Köprüsü	0.18	Kınık	1.48
Burhaniye	0.12	Küçükilet	0.23
Büyükbostancı	0.12	Manisa Köprüsü	0.14
Çakırbeyli	0.16	Sazköy	1.20
Çalıköy	0.09	Selçuk	0.12
Çatallar	0.19	Sinanhoca	3.32
Çıtak Köprüsü	0.15	Suçatı	0.20
Darıbükü	0.16	Şelale	3.68
Değirmenalanı	0.44	Topuz Damları	0.21
Dereköy	0.17	Yağcılı	0.38
Dereli	0.32	Yahyaköy	0.31
Döllük	0.37	Yemişendere	0.32
Eğrigöl	0.14	Yiğitler	0.57

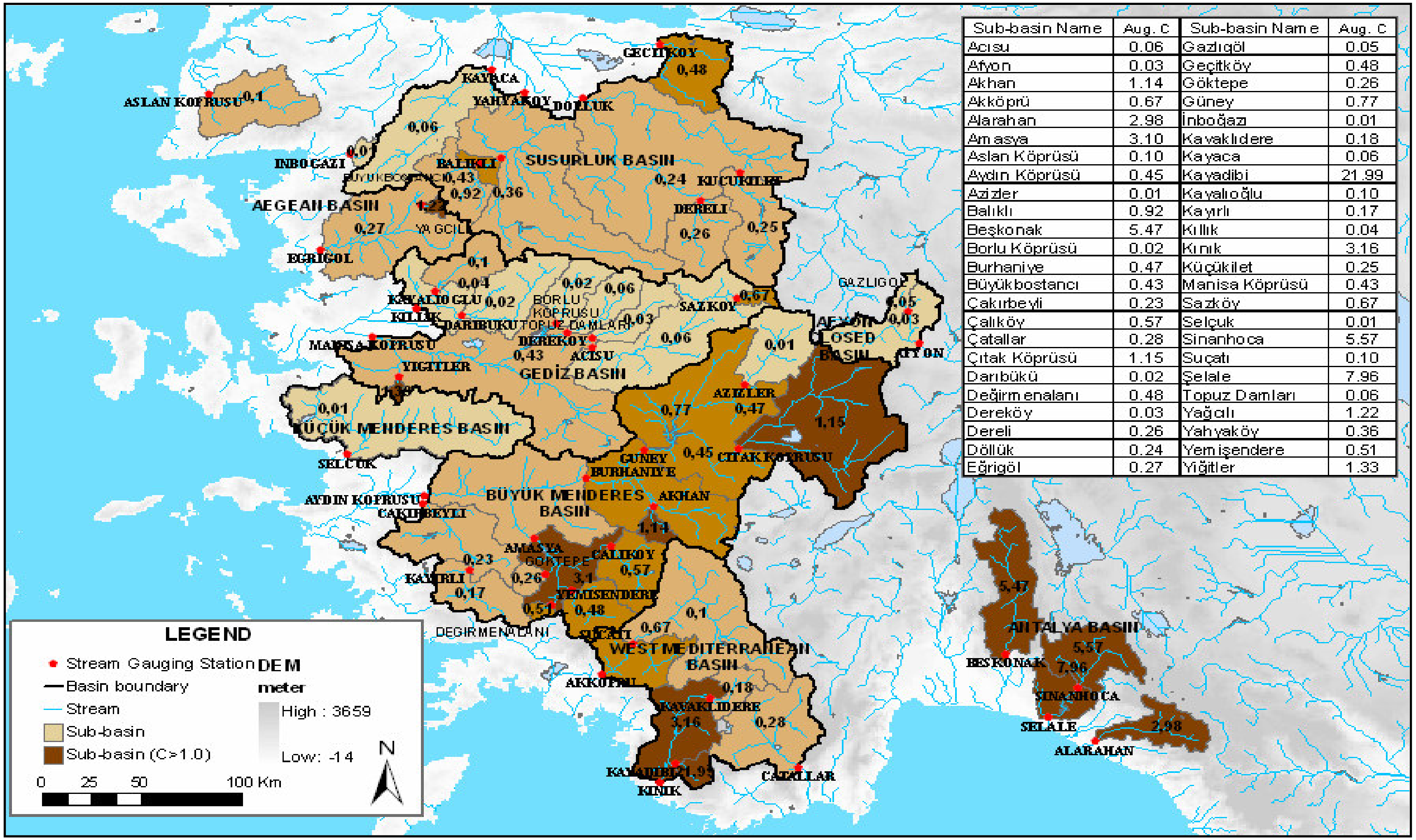
Figure 5.5 Sub-basins and their May runoff coefficients in the study area.

Sub-basin Name	Jun. C	Sub-basin Name	Jun. C
Acısu	0.17	Gazlıgöl	0.10
Afyon	0.06	Geçitköy	0.83
Akhan	0.91	Göktepe	0.25
Akköprü	0.52	Güney	0.23
Alarahan	6.01	İnboğazı	0.17
Amasya	0.46	Kavaklıdere	0.32
Aslan Köprüsü	0.23	Kayaca	0.20
Aydın Köprüsü	0.17	Kayadibi	17.87
Azizler	0.18	Kayalıoğlu	0.18
Balıklı	0.29	Kayırlı	0.25
Beşkonak	3.22	Kıllık	0.11
Borlu Köprüsü	0.15	Kınık	2.22
Burhaniye	0.21	Küçükilet	0.24
Büyükbostancı	0.14	Manisa Köprüsü	0.20
Çakırbeyli	0.17	Sazköy	1.03
Çalıköy	0.16	Selçuk	0.13
Çatallar	0.16	Sinanhoca	4.63
Çıtak Köprüsü	0.26	Suçatı	0.15
Darıbükü	0.14	Şelale	5.47
Değirmenalanı	0.47	Topuz Damları	0.13
Dereköy	0.09	Yağcılı	0.57
Dereli	0.28	Yahyaköy	0.29
Döllük	0.28	Yemişendere	0.32
Eğrigöl	0.13	Yiğitler	0.43

Figure 5.6 Sub-basins and their June runoff coefficients in the study area.

Sub-basin Name	Jul. C	Sub-basin Name	Jul. C
Acısu	0.07	Gazlıgöl	0.03
Afyon	0.02	Geçitköy	0.56
Akhan	0.78	Göktepe	0.47
Akköprü	0.64	Güney	0.52
Alarahan	2.47	İnboğazı	0.02
Amasya	2.33	Kavaklıdere	0.23
Aslan Köprüsü	0.12	Kayaca	0.10
Aydın Köprüsü	0.29	Kayadibi	65.32
Azizler	0.03	Kayalıoğlu	0.11
Balıklı	0.46	Kayırlı	0.21
Beşkonak	5.11	Kılık	0.06
Borlu Köprüsü	0.04	Kınık	3.21
Burhaniye	0.31	Küçükilet	0.26
Büyükbostancı	0.26	Manisa Köprüsü	0.33
Çakırbeyli	0.14	Sazköy	0.65
Çalıköy	0.44	Selçuk	0.05
Çatallar	0.27	Sinanhoca	6.93
Çıtak Köprüsü	0.69	Suçatı	0.12
Darıbükü	0.04	Şelale	8.85
Değirmenalanı	0.67	Topuz Damları	0.06
Dereköy	0.05	Yağcılı	0.87
Dereli	0.27	Yahyaköy	0.33
Döllük	0.24	Yemişendere	0.72
Eğrigöl	0.15	Yiğitler	0.38

Figure 5.7 Sub-basins and their July runoff coefficients in the study area.



Sub-basin Name	Aug. C	Sub-basin Name	Aug. C
Acısu	0.06	Gazlıgöl	0.05
Afyon	0.03	Geçitköy	0.48
Akhan	1.14	Göktepe	0.26
Akköprü	0.67	Güney	0.77
Alarahan	2.98	İnboğazı	0.01
Amasya	3.10	Kavaklıdere	0.18
Aslan Köprüsü	0.10	Kayaca	0.06
Aydın Köprüsü	0.45	Kayadibi	21.99
Azizler	0.01	Kayalıoğlu	0.10
Balıklı	0.92	Kayırlı	0.17
Beşkonak	5.47	Kıllık	0.04
Borlu Köprüsü	0.02	Kınık	3.16
Burhaniye	0.47	Küçükilet	0.25
Büyükbostancı	0.43	Manisa Köprüsü	0.43
Çakırbeyli	0.23	Sazköy	0.67
Çalıköy	0.57	Selçuk	0.01
Çatallar	0.28	Sinanhoca	5.57
Çıtak Köprüsü	1.15	Suçatı	0.10
Darıbükü	0.02	Şelale	7.96
Değirmenalanı	0.48	Topuz Damları	0.06
Dereköy	0.03	Yağcılı	1.22
Dereli	0.26	Yahyaköy	0.36
Döllük	0.24	Yemişendere	0.51
Eğrigöl	0.27	Yiğitler	1.33

Figure 5.8 Sub-basins and their August runoff coefficients in the study area.

Sub-basin Name	Sep. C	Sub-basin Name	Sep. C
Acısu	0.05	Gazlıgöl	0.10
Afyon	0.05	Geçitköy	0.20
Akhan	1.04	Göktepe	0.14
Akköprü	0.58	Güney	0.50
Alarahan	1.22	İnboğazı	0.005
Amasya	0.68	Kavaklıdere	0.25
Aslan Köprüsü	0.03	Kayaca	0.04
Aydın Köprüsü	0.22	Kayadibi	7.29
Azizler	0.02	Kayalıoğlu	0.04
Balıklı	0.18	Kayırlı	0.09
Beşkonak	3.15	Kıllık	0.02
Borlu Köprüsü	0.02	Kınık	1.65
Burhaniye	0.35	Küçükilet	0.24
Büyükbostancı	0.07	Manisa Köprüsü	0.23
Çakırbeyli	0.07	Sazköy	0.49
Çalıköy	0.23	Selçuk	0.004
Çatallar	0.32	Sinanhoca	1.49
Çıtak Köprüsü	0.53	Suçatı	0.13
Darıbükü	0.005	Şelale	3.36
Değirmenalanı	0.20	Topuz Damları	0.03
Dereköy	0.02	Yağcılı	0.25
Dereli	0.22	Yahyaköy	0.17
Döllük	0.15	Yemişendere	0.45
Eğrigöl	0.06	Yiğitler	0.09

Figure 5.9 Sub-basins and their September runoff coefficients in the study area.

Sub-basin Name	Oct. C	Sub-basin Name	Oct. C
Acısu	0.05	Gazlıgöl	0.03
Afyon	0.02	Geçitköy	0.16
Akhan	0.72	Göktepe	0.08
Akköprü	0.23	Güney	0.08
Alarahan	0.23	İnboğazı	0.03
Amasya	0.09	Kavaklıdere	0.09
Aslan Köprüsü	0.05	Kayaca	0.04
Aydın Köprüsü	0.09	Kayadibi	2.03
Azizler	0.02	Kayalıoğlu	0.03
Balıklı	0.07	Kayırlı	0.05
Beşkonak	0.74	Kıllık	0.02
Borlu Köprüsü	0.03	Kınık	0.53
Burhaniye	0.11	Küçükilet	0.12
Büyükbostancı	0.04	Manisa Köprüsü	0.10
Çakırbeyli	0.04	Sazköy	0.23
Çalıköy	0.06	Selçuk	0.01
Çatallar	0.07	Sinanhoca	0.27
Çıtak Köprüsü	0.08	Suçatı	0.10
Darıbükü	0.06	Şelale	0.66
Değirmenalanı	0.09	Topuz Damları	0.03
Dereköy	0.03	Yağcılı	0.16
Dereli	0.14	Yahyaköy	0.09
Döllük	0.09	Yemişendere	0.16
Eğrigöl	0.02	Yiğitler	0.08

Figure 5.10 Sub-basins and their October runoff coefficients in the study area.

Sub-basin Name	Nov. C	Sub-basin Name	Nov. C
Acısu	0.06	Gazlıgöl	0.05
Afyon	0.03	Geçitköy	0.20
Akhan	0.37	Göktepe	0.05
Akköprü	0.21	Güney	0.04
Alarahan	0.34	İnboğazı	0.07
Amasya	0.04	Kavaklıdere	0.14
Aslan Köprüsü	0.11	Kayaca	0.09
Aydın Köprüsü	0.06	Kayadibi	1.26
Azizler	0.04	Kayalıoğlu	0.03
Balıklı	0.10	Kayırlı	0.05
Beşkonak	0.67	Kıllık	0.02
Borlu Köprüsü	0.06	Kınık	0.42
Burhaniye	0.07	Küçükilet	0.11
Büyükbostancı	0.05	Manisa Köprüsü	0.07
Çakırbeyli	0.04	Sazköy	0.21
Çalıköy	0.03	Selçuk	0.01
Çatallar	0.06	Sinanhoca	0.40
Çıtak Köprüsü	0.05	Suçatı	0.09
Danbükü	0.03	Şelale	0.58
Değirmenalanı	0.15	Topuz Damları	0.06
Dereköy	0.04	Yağcılı	0.14
Dereli	0.12	Yahyaköy	0.08
Döllük	0.10	Yemişendere	0.16
Eğrigöl	0.04	Yiğitler	0.10

Figure 5.11 Sub-basins and their November runoff coefficients in the study area.

December average runoff coefficient value is 0.23. Şelale sub-basin has the largest runoff coefficient value with 0.88, and Beşkonak sub-basin comes next. Çıtak Köprüsü has smallest runoff coefficient value with 0.04, as in January and February. The other small runoff coefficient values belong to sub-basins, which are located east, west, southwest and south parts of the region such as Amasya and Çalıköy sub-basins (Figure 5.12).

5.1.2 Seasonal Runoff Coefficients

As it is seen in Table 5.1 seasonal runoff coefficients change between 0.15 and 0.34, and they are all smaller than the constant value used for Turkey.

Fall average runoff coefficient value is 0.15. Beşkonak sub-basin has the largest runoff coefficient value with 0.87, as in January. Şelale sub-basin has also large runoff coefficient value with 0.79, as in October. Selçuk sub-basin has the smallest runoff coefficient value with 0.01, as in August. East, southwest, northwest and middle parts of the region have small runoff coefficient values such as Gazlıgöl and Kayırlı sub-basins (Figure 5.13).

Winter average runoff coefficient value is 0.29. Sinanhoca sub-basin has the largest coefficient with 0.89, with Alarahan sub-basin coming next. Çıtak Köprüsü sub-basin has the smallest runoff coefficient value with 0.06. Generally middle part of the region has small runoff coefficient values (Figure 5.14).

Spring average runoff coefficient value is 0.34. Geçitköy sub-basin near Uludağ has the largest runoff coefficient value with 0.95, as in April, and Kavaklıdere and Sazköy sub-basins having the next large values. Çalıköy, Güney and Kıllık sub-basins have smallest runoff coefficient values. Again the middle part of the region has smaller runoff coefficients (Figure 5.15).

Summer average runoff coefficient value is 0.29, as in winter. Akhan sub-basin has the largest runoff coefficient value with 0.91. The large runoff coefficient values are obtained from Yağcılı, Sazköy and Geçitköy sub-basins. Afyon sub-basin has the smallest runoff coefficient with 0.04, as in May. Middle part of the study area has small runoff coefficients, such as Dereköy and Borlu Köprüsü sub-basins (Figure 5.16).

Sub-basin Name	Dec. C	Sub-basin Name	Dec. C
Acısu	0.12	Gazlıgöl	0.06
Afyon	0.05	Geçitköy	0.35
Akhan	0.39	Göktepe	0.11
Akköprü	0.33	Güney	0.05
Alarahan	0.58	İnboğazı	0.26
Amasya	0.05	Kavaklıdere	0.24
Aslan Köprüsü	0.29	Kayaca	0.35
Aydın Köprüsü	0.08	Kayadibi	1.17
Azizler	0.08	Kayalıoğlu	0.11
Balıklı	0.30	Kayırlı	0.09
Beşkonak	0.84	Kıllık	0.06
Borlu Köprüsü	0.23	Kınık	0.41
Burhaniye	0.09	Küçükilet	0.14
Büyükbostancı	0.15	Manisa Köprüsü	0.10
Çakırbeyli	0.09	Sazköy	0.25
Çalıköy	0.05	Selçuk	0.05
Çatallar	0.06	Sinanhoca	0.73
Çıtak Köprüsü	0.04	Suçatı	0.15
Danbükü	0.16	Şelale	0.88
Değirmenalanı	0.32	Topuz Damları	0.20
Dereköy	0.13	Yağcılı	0.25
Dereli	0.16	Yahyaköy	0.24
Döllük	0.19	Yemişendere	0.41
Eğrigöl	0.16	Yiğitler	0.31

Figure 5.12 Sub-basins and their December runoff coefficients in the study area

Sub-basin Name	Fall C	Sub-basin Name	Fall C
Acısu	0.06	Gazlıgöl	0.05
Afyon	0.03	Geçitköy	0.18
Akhan	0.54	Göktepe	0.07
Akköprü	0.26	Güney	0.10
Alarahan	0.35	İnboğazı	0.05
Amasya	0.11	Kavaklıdere	0.13
Aslan Köprüsü	0.09	Kayaca	0.07
Aydın Köprüsü	0.09	Kayadibi	2.07
Azizler	0.03	Kayalıoğlu	0.03
Balıklı	0.10	Kayırlı	0.05
Beşkonak	0.87	Kıllık	0.02
Borlu Köprüsü	0.04	Kınık	0.56
Burhaniye	0.11	Küçükilet	0.13
Büyükbostancı	0.05	Manisa Köprüsü	0.10
Çakırbeyli	0.05	Sazköy	0.25
Çalıköy	0.06	Selçuk	0.01
Çatallar	0.08	Sinanhoca	0.43
Çıtak Köprüsü	0.11	Suçatı	0.10
Darıbükü	0.03	Şelale	0.79
Değirmenalanı	0.13	Topuz Damları	0.04
Dereköy	0.04	Yağcılı	0.16
Dereli	0.14	Yahyaköy	0.10
Döllük	0.11	Yemişendere	0.18
Eğrigöl	0.04	Yiğitler	0.09

Figure 5.13 Sub-basins and their fall runoff coefficients in the study area.

Sub-basin Name	Win. C	Sub-basin Name	Win. C
Acısu	0.22	Gazlıgöl	0.19
Afyon	0.10	Geçitköy	0.45
Akhan	0.47	Göktepe	0.17
Akköprü	0.42	Güney	0.07
Alarahan	0.72	İnboğazı	0.39
Amasya	0.08	Kavaklıdere	0.37
Aslan Köprüsü	0.42	Kayaca	0.52
Aydın Köprüsü	0.12	Kayadibi	1.34
Azizler	0.15	Kayalıoğlu	0.20
Balıklı	0.48	Kayırlı	0.17
Beşkonak	1.01	Kıllık	0.09
Borlu Köprüsü	0.34	Kınık	0.53
Burhaniye	0.12	Küçükilet	0.26
Büyükbostancı	0.24	Manisa Köprüsü	0.16
Çakırbeyli	0.18	Sazköy	0.31
Çalıköy	0.09	Selçuk	0.11
Çatallar	0.08	Sinanhoca	0.89
Çıtak Köprüsü	0.06	Suçatı	0.21
Darıbükü	0.25	Şelale	1.11
Değirmenalanı	0.40	Topuz Damları	0.29
Dereköy	0.21	Yağcılı	0.32
Dereli	0.26	Yahyaköy	0.38
Döllük	0.30	Yemişendere	0.48
Eğrigöl	0.22	Yiğitler	0.48

Figure 5.14 Sub-basins and their winter runoff coefficients in the study area.

Sub-basin Name	Spr. C	Sub-basin Name	Spr. C
Acısu	0.24	Gazlıgöl	0.26
Afyon	0.15	Geçitköy	0.95
Akhan	0.55	Göktepe	0.31
Akköprü	0.60	Güney	0.10
Alarahan	1.94	İnboğazı	0.43
Amasya	0.13	Kavaklıdere	0.87
Aslan Köprüsü	0.45	Kayaca	0.53
Aydın Köprüsü	0.13	Kayadibi	3.34
Azizler	0.24	Kayalıoğlu	0.25
Balıklı	0.41	Kayırlı	0.26
Beşkonak	1.80	Kıllık	0.10
Borlu Köprüsü	0.26	Kınık	1.09
Burhaniye	0.12	Küçükilet	0.30
Büyükbostancı	0.21	Manisa Köprüsü	0.16
Çakırbeyli	0.24	Sazköy	0.85
Çalıköy	0.10	Selçuk	0.14
Çatallar	0.17	Sinanhoca	2.19
Çıtak Köprüsü	0.13	Suçatı	0.30
Danbükü	0.24	Şelale	2.37
Değirmenalanı	0.50	Topuz Damları	0.26
Dereköy	0.20	Yağcılı	0.39
Dereli	0.41	Yahyaköy	0.44
Döllük	0.46	Yemişendere	0.48
Eğrigöl	0.20	Yiğitler	0.68

Figure 5.15 Sub-basins and their spring runoff coefficients in the study area.

Sub-basin Name	Sum. C	Sub-basin Name	Sum. C
Acısu	0.11	Gazlıgöl	0.07
Afyon	0.04	Geçitköy	0.68
Akhan	0.91	Göktepe	0.30
Akköprü	0.59	Güney	0.46
Alarahan	3.81	İnboğazı	0.11
Amasya	1.62	Kavaklıdere	0.27
Aslan Köprüsü	0.18	Kayaca	0.14
Aydın Köprüsü	0.28	Kayadibi	25.59
Azizler	0.09	Kayalıoğlu	0.15
Balıklı	0.40	Kayırlı	0.22
Beskonak	4.13	Kıllık	0.08
Borlu Köprüsü	0.07	Kınık	2.69
Burhaniye	0.30	Küçükilet	0.25
Büyükbostancı	0.20	Manisa Köprüsü	0.30
Çakırbeyli	0.17	Sazköy	0.82
Çalıköy	0.34	Selçuk	0.09
Çatallar	0.21	Sinanhoca	5.38
Çıtak Köprüsü	0.57	Suçatı	0.13
Darıbükü	0.08	Şelale	6.83
Değirmenalanı	0.52	Topuz Damları	0.09
Dereköy	0.07	Yağcılı	0.77
Dereli	0.27	Yahyaköy	0.32
Döllük	0.26	Yemişendere	0.44
Eğrigöl	0.17	Yiğitler	0.47

Figure 5.16 Sub-basins and their summer runoff coefficients in the study area.

5.1.3 Annual Runoff Coefficient

Annual average runoff coefficient value is 0.27 for the whole region, which is again smaller than the constant value used for Turkey. Alarahan sub-basin has the largest runoff coefficient value with 0.95, as in February. Southwest part of the region generally has large runoff coefficient values, and also Geçitköy sub-basin and the upstreams of basins have larger coefficients. Kıllık sub-basin has the smallest runoff coefficients with 0.08, as in spring. The other small values belong to sub-basins at the middle part of the region, such as Selçuk and Aydın Köprüsü sub-basins (Figure 5.17).

5.2 Evaluation of the Significant Parameters for Runoff Coefficient in the Study Area

Collected and determined data (basin characteristics) of the basins in the study area are used in regression analyses in different forms to obtain acceptable results. First of all, both response and predictor(s) data were used in linear regression equation without any transformation on them. Then the exponential non-linear equation was converted to linear form by taking logarithms of both sides of Equation 4.1. Logarithmic regression equation (Equation 4.2) can be put in the form of a linear regression equation (Equation 4.3). Lastly, the data of both predictor and response variables were transformed by Box-Cox transformation which is explained in Chapter 4. Thus, the relation between predictor and response variables is accepted as linear.

The data, in these three forms, were then analyzed by stepwise regression analysis. The best results were obtained with Box-Cox transformed data. The measure of fit by the model is expressed by the value of R-sq, where the larger the R-sq value, the better the model fits the data. Table 5.2 shows a sample output for January runoff coefficient of whole study area as the response variable and 16 basin parameters as predictor variables, tested one at a time with 85% significant level.

Sub-basin Name	Ann. C	Sub-basin Name	Ann. C
Acısu	0.18	Gazlıgöl	0.16
Afyon	0.09	Geçitköy	0.53
Akhan	0.55	Göktepe	0.19
Akköprü	0.44	Güney	0.13
Alarahan	0.95	İnboğazı	0.28
Amasya	0.19	Kavaklıdere	0.44
Aslan Köprüsü	0.32	Kayaca	0.37
Aydın Köprüsü	0.13	Kayadibi	2.43
Azizler	0.14	Kayalıoğlu	0.17
Balıklı	0.36	Kayırlı	0.17
Beşkonak	1.32	Killık	0.08
Borlu Köprüsü	0.23	Kınık	0.74
Burhaniye	0.14	Küçükilet	0.24
Büyükbostancı	0.18	Manisa Köprüsü	0.16
Çakırbeyli	0.16	Sazköy	0.50
Çalıköy	0.11	Selçuk	0.09
Çatallar	0.12	Sinanhoca	1.23
Çıtak Köprüsü	0.15	Suçatı	0.20
Danbükü	0.19	Şelale	1.51
Değirmenalanı	0.36	Topuz Damları	0.21
Dereköy	0.16	Yağcılı	0.32
Dereli	0.28	Yahyaköy	0.32
Döllük	0.29	Yemişendere	0.42
Eğrigöl	0.17	Yiğitler	0.43

Figure 5.17 Sub-basins and their annual runoff coefficients in the study area.

Table 5. 2 Results of regression analyses with different forms of data for January runoff coefficient.

	Raw data		Logarithmic data		Box-cox transformed data	
	R-sq (%)	R-sq(adj) (%)	R-sq (%)	R-sq(adj) (%)	R-sq (%)	R-sq(adj) (%)
P	9.26	7.2	14.19	12.24	15.14	13.21
A	10.70	8.67	16.67	14.78	16.67	14.78
TRL	10.37	8.34	14.96	13.03	16.69	14.79
MCL	6.02	3.89	9.20	7.14	9.87	7.82
L_h	6.61	4.49	10.37	8.33	10.64	8.6
W_h	14.27	12.32	21.60	19.82	24.11	22.38
MCS	12.19	10.19	23.34	21.60	24.63	22.91
SO	7.61	5.51	12.93	10.95	14.72	12.78
TNB	10.72	8.69	16.54	14.64	16.54	14.64
SI1	5.04	2.88	*	*	*	*
SI2	*	*	*	*	*	*
K_c	*	*	*	*	*	*
Dd	*	*	*	*	*	*
Df	*	*	*	*	*	*
S	23.27	21.53	10.63	8.60	8.20	6.11
Rb	*	*	8.36	6.28	9.45	7.4

* The relation between the variable and the runoff coefficient is not statistically significant for 0.15 α level.

If runoff coefficient of a basin is greater than 1.0, it is not used in the regression analyses. For example, there were two sub-basins, with January runoff coefficients greater than 1.0 in the study area, and therefore, analysis was made by using the remaining 46 sub-basins. The smallest R-sq values were seen with raw data, except the mean basin slope (S). Using Box-Cox transformed data in linear regression analyses, gave the largest R-sq values except for the mean basin slope parameter. Consequently, the data which were formed by Box-Cox transformation were used in the stepwise regression analyses for the rest of the study.

The significant parameters were evaluated for annual runoff coefficient of 44 sub-basins in the region. They come from eight basins; eight from Susurluk, four from Aegean, 10 from Gediz, one from Küçük Menderes, 13 from Büyük Menderes, five from West Mediterranean, one from Antalya, and two from Afyon Closed Basins. It was also examined whether there is any relation between basin parameters and seasonal runoff coefficients. The numbers of basins taken into consideration are 47, 45, 42 and 41 for fall, winter, spring and summer respectively. Table 5.3 shows the best R-sq (adj) values of the stepwise regression analyses with single, two and three parameters for seasonal and annual runoff coefficients of the region.

Table 5. 3 Best result of analyses with single, two, and three parameters for runoff coefficients of whole region.

	Single Parameter			Two Parameters			Three Parameters		
		R-sq (adj) (%)	Correlation coefficient		R-sq (adj) (%)	Correlation coefficient		R-sq (adj) (%)	Correlation coefficient
Winter	MCS	23.56	0.49	MCS, W_h	28.68	0.54	MCS, W_h, K_c	33.39	0.58
Spring	MCS	29.41	0.54	MCS, W_h	35.21	0.59			
Summer	S	22.23	0.47	MCS, W_h	25.95	0.51			
Fall	S	29.12	0.54	MCS, MCL	37.92	0.62			
Annual	MCS	35.76	0.60	MCS, SI1	39.91	0.63			

As seen in Table 5.3, correlation coefficient changes from 0.47 to 0.54 for seasonal runoff coefficient, and it is 0.60 for annual coefficient with single parameter. The most important parameter is MCS, then S for this case.

In two parameter case, MCS is again in the equations with W_h in three seasons and MCL and SI1 in the other two cases as the second parameter. Correlation coefficient for these, changes from 0.51 to 0.62 for seasonal runoff coefficient, and it is 0.63 for annual coefficient.

In three parameter situation, only one case was significant which is for winter with correlation coefficient of 0.58 and MCS, W_h and K_c as the significant parameters.

For annual runoff coefficient, the main channel and the mean basin slopes are significant parameters with R-sq (adj) value of 35.76% and 19.83% respectively. Only the R-sq (adj) value of main channel length and basin length are less than 10% in single parameter case. All the combinations of the two parameters, which do not have high correlation between them, were examined by add-remove variables method of stepwise regression analysis. The main channel slope (MCS) and the basin shape index (SI1) combination gives highest correlation with R-sq (adj) value of 39.91%. The main channel slope and the drainage density (Dd) combination have the second larger value of R-sq (adj) with 38.87%. The combinations with the three parameters were examined by taking into the consideration the correlations between the predictors. Thus, six combinations with three parameters were formed, and their R-sq (adj) values change between 30.76% and 34.84% (Table A.10). All these six combinations were formed by adding the main basin slope to the combinations of the other two parameters. The combinations with four parameters were also examined. But the relations between the parameters and the annual runoff coefficients are not statistically significant for 0.15 α level.

5.3 Evaluation of the Significant Parameters for the Runoff Coefficients of Each Basin

The significant parameters of Susurluk, Aegean, Gediz, Büyük Menderes and West Mediterranean Basins for seasonal and annual runoff coefficients are given in Table 5.4 as a summary while the detailed tables are given in Appendix. The reasons for not including Antalya, Afyon Closed and Küçük Menderes Basins are explained in section 5.5.

Only two of the basin parameters, drainage frequency (Df) and mean basin slope (S), were found significant in stepwise regression analyses for annual runoff coefficient for Susurluk Basin. The values of R-sq (adj) of the drainage frequency and the mean basin slope are 32.83% and 27.31% respectively (Table A.1).

For Susurluk Basin, if the drainage frequency parameter is used in the analysis, R-sq (adj) values are 52.64% and 32.83% for summer and annual runoff coefficients respectively. For spring runoff coefficient, when the mean basin slope or drainage frequency is used alone in the analysis, both of them give similar results with 50.23% and 49.45% R-sq (adj) values. There is not any statistically significant relation between the basin parameters and winter runoff coefficient. For fall runoff coefficient, the drainage density gives 51.23% R-sq (adj) value. When the drainage density is used with the drainage frequency, value becomes 63.93% (Table 5.4) in two parameter case. There are no significant cases for the other times on three parameter cases in this basin.

For Aegean Basin, when the drainage density parameter is used alone in the analyses, R-sq (adj) value is 66.54% for spring runoff coefficient. The significant basin parameter is the drainage density with 72.85% R-sq (adj) value for annual runoff coefficient. The R-sq (adj) values are 98.99%, 99.75%, 99.94%, 99.99%, 99.99% and 100.00% respectively with adding perimeter, stream order, basin length, main channel slope, total number of branches or bifurcation ratio parameters as the second parameter to the drainage density for annual runoff coefficient. As it is seen these combinations give very good results for explaining the annual runoff coefficient. For spring runoff coefficient, the drainage density is used with basin width, then R-sq (adj) value becomes 99.72%. But, there is not any statistically significant relation between the basin parameters and runoff coefficients for fall, winter and summer (Table 5.4).

Table 5. 4 The best R-sq (adj) values (%) obtained with 1, 2 and 3 parameters for runoff coefficients of different basins.

	ANNUAL					
BASIN	Single Parameter		Two Parameters		Three Parameters	
Susurluk	Df	32.83				
Aegean	Dd	72.85	Dd, Rb	100		
Gedız	MCS	82.25	MCS, Dd	91.39		
Büyük Menderes	MCS	64.86	MCS, Rb	78.24	MCS, Rb, Df	84.26
West Medıterranean	SI1	60.54				
	FALL					
BASIN	Single Parameter		Two Parameters		Three Parameters	
Susurluk	Dd	51.23	Dd, Df	63.93		
Aegean						
Gedız	S	62.85	S, MCL	76.73	S, TRL, Rb	81.29
Büyük Menderes	S	26.58	MCS, Df	60.82		
West Medıterranean	SI1	74.68				
	WINTER					
BASIN	Single Parameter		Two Parameters		Three Parameters	
Susurluk						
Aegean						
Gedız	MCS	83.99				
Büyük Menderes	Rb	57.83	Rb, MCS	77.83	Rb, MCS, SI1	83.42
West Medıterranean	SI1	44.64				
	SPRING					
BASIN	Single Parameter		Two Parameters		Three Parameters	
Susurluk	S	50.23				
Aegean	Dd	66.54	Dd, W_h	99.72		
Gedız	MCS	80.99	MCS, Dd	88.37		
Büyük Menderes	W_h	65.55	MCS, Rb	79.70	W_h, K_c, MCS	86.41
West Medıterranean	Rb	67.95	SI1, S	97.93		
	SUMMER					
BASIN	Single Parameter		Two Parameters		Three Parameters	
Susurluk	Df	52.64				
Aegean						
Gedız	S	72.07	S, SI2	85.15		
Büyük Menderes	S	13.69	S, Df	27.52	S, Df, SI1	48.21
West Medıterranean						

For Gediz Basin, the most significant parameter is the main channel slope with the R-sq (adj) value of 82.25% for annual runoff coefficient (Table 5.4). The second important single parameter is S with 74.47% value. The bifurcation ratio (Rb) and the basin area are the other significant parameters with the values of 55.03% and 54.63%, respectively. The R-sq (adj) values of the rest of the single parameters are less than 50%. The combinations with two parameters are MCS-Dd, Rb-S, Rb-Df, TNB-Df with 91.39%, 82.65%, 67.97% and 44.95% R-sq (adj) values respectively (Table A.4).

For fall runoff coefficient of Gediz Basin, if the mean basin slope is used alone in the analysis, R-sq (adj) value is 62.85% (Table 5.4). When the drainage density is added to it value becomes 73.66%, and with the basin shape index (SI2) as the third parameter, the value increases to 80.85%. When bifurcation ratio is used as the forth parameter, the R-sq (adj) value equals to 88.99%. The largest R-sq (adj) value is 92.34% with five parameters as; the mean basin slope, the drainage density, the gravelius index, the bifurcation ratio and the drainage frequency (Table A.4). For winter runoff coefficient, the main channel slope parameter has the largest R-sq (adj) value with 83.99%. When the main channel slope parameter is used alone in the analysis, the R-sq (adj) value is 80.99% for spring runoff coefficient (Table A.4). When the drainage density is added as the second parameter, the R-sq (adj) value becomes 88.37%. For summer runoff coefficient of Gediz Basin, when the mean basin slope is used alone in the analysis, R-sq (adj) value equals to 72.07%. If the basin shape index (SI2) is added as the second parameter, the value becomes 85.15% (Table 5.4).

For Büyük Menderes Basin, the main channel slope, the mean basin slope and the total number of branches (TNB) are the most important parameters with 64.86%, 56.77%, 52.01% R-sq (adj) values, respectively. The remaining single parameters have less than 50% R-sq (adj) values. There are 13 combinations with two parameters for Büyük Menderes Basin (Table A.5). When the bifurcation ratio parameter is added to the main channel slope as the second parameter, the R-sq (adj) value becomes 78.24%. Then if the drainage frequency is added as the third parameter, the R-sq (adj) value increases to 84.26% (Table 5.4).

For fall runoff coefficient of Büyük Menderes Basin, the mean basin slope has 26.58% R-sq (adj) value (Table 5.4), and the drainage frequency has 22.96% value. When these two parameters are used together, the R-sq (adj) value becomes 57.50% (Table A.5). When the main channel slope and drainage frequency parameters are used together in the analysis, the R-sq (adj) value becomes 60.82% (Table 5.4).

For winter runoff coefficient of Büyük Menderes Basin, when the bifurcation ratio parameter is used alone, the R-sq (adj) value is 57.83%. When main channel slope parameter is added, the R-sq (adj) value becomes 77.83%. Then, when basin shape index (SI1) is included as the third parameter, value increases to 83.42%, which is the largest R-sq (adj) value for winter runoff coefficient (Table 5.4).

For spring runoff coefficient of Büyük Menderes Basin, the largest R-sq (adj) value is obtained as 65.55% with the basin width as the single parameter in the analysis. When the main channel slope and the bifurcation ratio parameters are used together in the analysis, the R-sq (adj) value becomes 79.70%. If the basin width, the Gravelius index and the main channel slope parameters are used in the analysis, the R-sq (adj) value increases to 86.41% (Table 5.4). There is no big difference between this R-sq (adj) value, and the largest R-sq (adj) value as 86.49%, which is obtained using four parameters with main channel slope, stream order, basin shape index (SI1) and drainage frequency (Table A.5).

For summer runoff coefficient of Büyük Menderes Basin, when the mean basin slope parameter is used alone in the analysis, the R-sq (adj) value is 13.69%. If the drainage frequency is added as the second parameter, the R-sq (adj) value increases to 27.52%, and when the basin shape index (SI1) is added as the third parameter, the value becomes 48.21% (Table 5.4).

For West Mediterranean Basin, only the basin shape index (SI1) is significant parameter for annual runoff coefficient with the value of R-sq (adj) as 60.54%. When SI1 is used alone in the analysis, the R-sq (adj) value equals to 74.68%, 44.64%, and 61.30% for fall, winter, and spring runoff coefficients, respectively (Table 5.4). If the bifurcation ratio is used alone in the analysis, the result shows that the R-sq (adj) value equals to 67.95% for spring runoff coefficient. If the basin shape index (SI1) and the mean basin slope are used together in the analysis for spring runoff coefficient, the R-sq (adj) value becomes 97.93% (Table A.3). There is not any statistically significant relation between the basin parameters and summer runoff coefficient.

5.4 Evaluation of the Significant Parameters for Seasonal and Annual Runoff Coefficient for Sub-Basins that are not Affected by Dams or Groundwater Input

Results given above were obtained by using data of sub-basins in the region, which have seasonal and annual runoff coefficient values less than 1.0, without considering whether there are dams on the streams or not. But in fact there are a number of dams in the region, and they affect the natural flow. Therefore, such streams are found and their sub-basins are excluded from the analyses. The findings of the new sets of analysis are given below. The best R-sq (adj) values of the stepwise regression analyses with 1, 2 and 3 parameters for seasonal and annual runoff coefficients of these basins are shown in Table 5.5. The detailed results are given in tables A.6, A.7, A.8 and A.9 for Susurluk, Gediz, Büyük Menderes and West Mediterranean Basins, respectively.

Table 5.5 The best R-sq (adj) values (%) of analyses for the basins, which are not affected by dams or groundwater input.

	ANNUAL					
BASIN	Single Parameter		Two Parameters		Three Parameters	
Susurluk						
Gediz	MCS	83.02	MCS, Dd	92.97		
Büyük Menderes	W_h	60.34	MCS, Rb	80.97		
West Mediterranean	SI1	63.45	SI1, K_c	99.75		
	FALL					
BASIN	Single Parameter		Two Parameters		Three Parameters	
Susurluk	Dd	69.89				
Gediz	S	71.73	S, Dd	81.65		
Büyük Menderes	S	70.91	S, Df	85.23		
West Mediterranean						
	WINTER					
BASIN	Single Parameter		Two Parameters		Three Parameters	
Susurluk	MCL	42.30				
Gediz	MCS	82.15	Rb, Df	75.81	Rb, Df, TRL	86.48
Büyük Menderes	W_h	53.62	MCS, Rb	82.10		
West Mediterranean	SI1	81.14				
	SPRING					
BASIN	Single Parameter		Two Parameters		Three Parameters	
Susurluk	Df	50.54	Df, MCS	84.54	Df, MCS, SI2	98.92
Gediz	S	80.29	MCS, Dd	86.96		
Büyük Menderes	MCS	62.81	MCS, L_h	90.37	MCS, TRL, Rb	94.15
West Mediterranean	Rb	67.95	SI1, S	97.93		
	SUMMER					
BASIN	Single Parameter		Two Parameters		Three Parameters	
Susurluk	TNB	66.10				
Gediz	S	81.50				
Büyük Menderes	S	77.75				
West Mediterranean						

5.4.1 Susurluk Basin

There are seven dams in Susurluk basin, which are Çaygören, Büyükorhan, Çavdarhisar, Kayaboğazı, Doğancı, Demirtaş and Gölbaşı Dams. These dams are generally located at the upstream parts of the basin. Some of them have little effect on the streams according to their irrigation capacities. In the light of this information, only Kayaca, Büyükbostancı, Balıklı, Dereli and Geçitköy sub-basins are chosen for regression analyses.

For fall runoff coefficient, the drainage density parameter has the largest R-sq (adj) value with 69.89%. For summer runoff coefficient, the total number of branches has the largest R-sq (adj) value with 66.10%.

For spring runoff coefficient, when the drainage frequency is used as a single parameter in the analyses giving the largest R-sq (adj) value as 50.54%. When main channel slope is added as a second parameter, the R-sq (adj) value increases to 84.54%, and when the basin shape index (SI2) is added as a third parameter, the value becomes 98.92%.

The main channel length has the largest R-sq (adj) value with 42.30% for winter runoff coefficient. The results also show that there is not any statistically significant relation between basin parameters and annual runoff coefficient.

5.4.2 Gediz Basin

There are three dams in this basin, which are Demirköprü, Afşar and Derbent Dams. Analyses are done with nine sub-basins, which are not affected by these dams. They are Kayalıoğlu, Kıllık, Yiğitler, Darıbükü, Borlu Köprüsü, Topuz Damları, Dereköy, Acısu and Sazköy sub-basins.

For annual runoff coefficient, the main channel slope has the largest R-sq (adj) value with 83.02%. When the drainage density is added as a second parameter, the value increases to 92.97%. For fall runoff coefficient, the mean basin slope has the largest R-sq (adj) value with 71.73%. The drainage density and the mean basin slope have together the largest R-sq (adj) value as 81.65%. The mean basin slope has also the largest R-sq (adj) values with 81.50% and 80.29% for summer and spring runoff coefficients respectively.

The mean basin slope is used as a single parameter in the analyses giving the largest R-sq (adj) value as 80.29% for spring runoff coefficient. The main channel slope and drainage density have together the largest R-sq (adj) value with 86.96% for spring runoff coefficient. The main channel slope has the largest R-sq (adj) value with 82.15% for winter runoff coefficient. The bifurcation ratio, the drainage frequency and the total river length have together the largest R-sq (adj) value with 86.48% for winter runoff coefficient. If the mean basin slope is added as a fourth parameter, the R-sq (adj) value increases to 91.98% for winter runoff coefficient.

5.4.3 Büyük Menderes Basin

There are seven dams in this basin being; Karpuzlu, Topcam, Kemer, Adıgüzel, Çindere, Işıklı and Örenler Dams. Azizler, Akhan, Çalıköy, Değirmenalanı, Yemişendere, Göktepe and Kayırlı sub-basins, which are not affected by these dams, are examined whether there is any significant relation between the basin parameters and runoff coefficients.

For annual runoff coefficient, the basin width has the largest R-sq (adj) value with 60.34%. The main channel slope and the bifurcation ratio together have 80.97% value. For fall runoff coefficient, the mean basin slope has R-sq (adj) value of 70.91%. When the drainage frequency is added as a second parameter, the value becomes 85.23%. For summer runoff coefficient, the mean basin slope has the largest R-sq (adj) value with 77.75%. For spring runoff coefficient, the main channel slope has 62.81% R-sq (adj) value. If the basin length is added to it as a second parameter, the R-sq (adj) value increases to 90.37%. Main channel slope, total river length and bifurcation ratio have together 94.15% R-sq (adj) value. For winter runoff coefficient, the basin width individually has 53.62% R-sq (adj) value. The main channel slope and the bifurcation ratio have together the largest R-sq (adj) value as 82.10%.

5.4.4 West Mediterranean Basin

In this basin, Kayadibi and Kınık sub-basins have runoff coefficient values larger than 1.0. They have obviously karstic regions and the streams are fed from groundwater. Therefore, the other sub-basins of West Mediterranean Basin, Suçatı, Akköprü, Kavaklıdere and

Çatallar, are used in regression analyses to find out significant parameters for runoff coefficients.

Basin shape index (SI1) has 63.45% and 81.14% R-sq (adj) value for annual and winter runoff coefficients respectively. For annual runoff coefficient, when the Gravelius index (K_c) is added as a second parameter, the largest R-sq (adj) value becomes 99.75%. For spring runoff coefficient, the bifurcation ratio has 67.95% R-sq (adj) value. The basin shape index (SI1) and the mean basin slope have together 97.93% R-sq (adj) value for spring runoff coefficient. But there is not any significant relation between the basin parameters and fall and summer runoff coefficient.

5.5 Problems of Antalya, Afyon and Küçük Menderes Basins

After the inspection of collected data it is realized that Antalya, Afyon Closed and Küçük Menderes Basins can not be included in the study as individual basins to find their significant parameters for runoff coefficient. The reasons are explained below for each basin separately.

5.5.1 Antalya Basin

In this study, four stream gauging stations (SGS) of Electrical Power Resources Survey and Development Administration (EİE) and their corresponding sub-basins were used from Antalya Basin. These stations are Alarahan on Alara Stream with number 917, Beşkonak on Köprüçay with number 902, Sinanhoca and Şelale on Manavgat Stream with numbers of 912 and 918 respectively.

There are three precipitation stations, Cevizli and Akseki being inside the sub-basin and Manavgat approximately 2.5 km away from its boundary. Table 5.6 shows weighted areas of stations which were used for calculating areal mean precipitation of the sub-basin.

As it is seen in Figure 5.18, the values of runoff coefficients are greater than 1.0 between January and September, and also for winter, spring, summer and annual (Figure 5.19).

Table 5. 6 POSs and their weighted areas for sub-basin of Şelale SGS.

Province	Name	No	Weighted Area
Antalya	Cevizli	7899	0.425
Antalya	Akseki	8229	0.449
Antalya	Manavgat	17954	0.126

The climate of Antalya Basin is the Mediterranean type. Most of the rainfall occurs in winter, and summer months are very hot, thus there exist arid areas in summer. Consequently, it is expected that the discharges of rivers should increase in winter, and decrease in summer. But, this region has large karstic areas, which have lots of fractures, channels and caves. In rainy months, a large part of the rain leaks to underground from the fractures of the karstic formations, which prevent the increase in discharges of the rivers in winter. Then, the groundwater feeds the rivers in summer. Hence, this situation prevents drying of the rivers and of decreasing the discharges in summer.

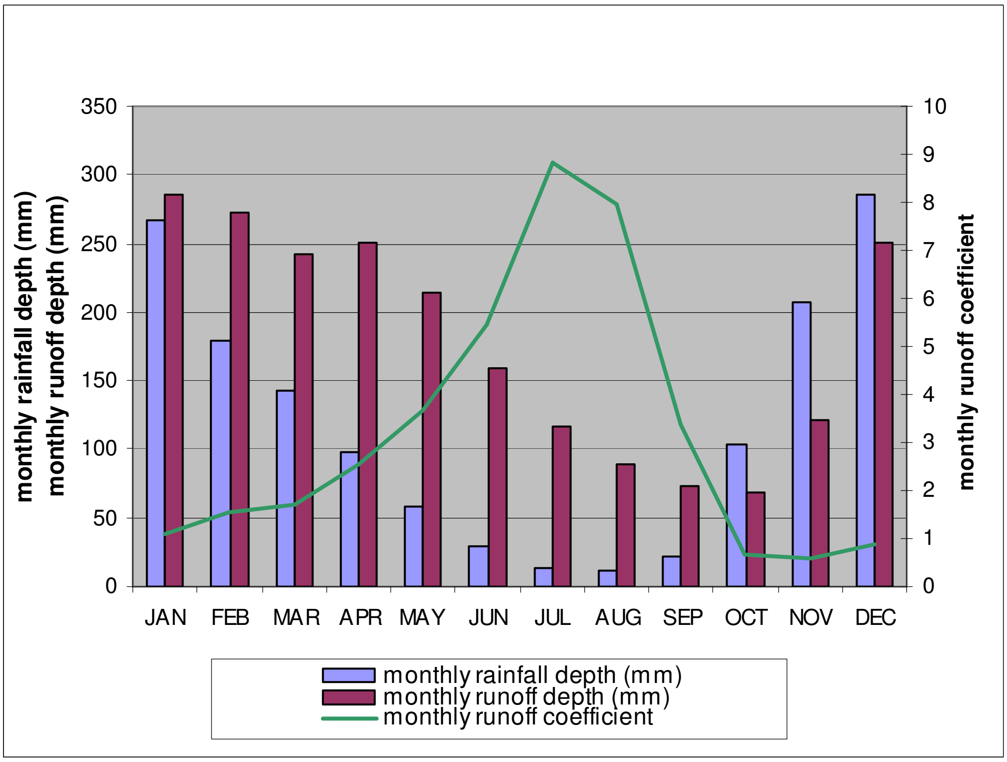


Figure 5. 18 Monthly total rainfall-runoff depths, and runoff coefficients of Şelale sub-basin.

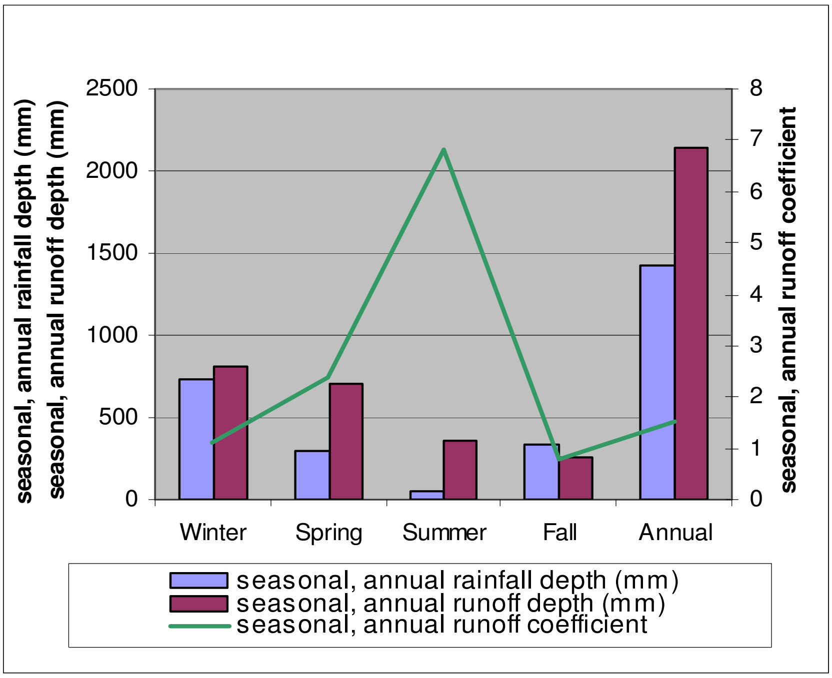


Figure 5. 19 Seasonal and annual total rainfall-runoff depths, and runoff coefficients of Şelale sub-basin.

A report (DSİ, 2004) about Manavgat Stream Basin reveals that groundwater feeds Manavgat Stream in a similar way as explained above. Manavgat Stream basin is in between Taurus Mountains and the Mediterranean Sea. Approximately 65% of its water potential comes from karstic region. Dumanlı Underground River, which is under Oymapınar Dam Lake and supplies 1/3 of water potential of the dam, is the biggest karstic spring of the world with 38 m^3/s average discharge from one outfall. The surface runoff of the Manavgat Stream is more than 2-6 times of total rainfall over its drainage area, and comes from karstic aquifers in the region. This is the main reason for runoff coefficient being higher than 1.0 in Antalya Basin. Another reason may be the location of precipitation gages. It is very likely that the stations do not represent the distribution of rainfall in the areal mean precipitation of sub-basins sufficiently due to the topographic conditions. Most of the POSs are located near the sea in the region not representing the inland areas.

5.5.2 Afyon Closed and Küçük Menderes Basins

There are two sub-basins chosen from Afyon Closed Basin, which are Gazlıgöl and Sivrikaya, and only one sub-basin, Selçuk, from Küçük Menderes Basin, due to the lack of data. So, there are not enough data for applying the regression analyses, due to the number of sub-basins from these two basins. Therefore, individual basin analysis was not made for these basins, but their basin parameters and runoff coefficients were used in the regression analyses for the whole region.

The sub-basin of Afyon SGS contains the sub-basin of Gölovası SGS which is at the upstream. There are little differences between their monthly, seasonal and annual runoff coefficients, while the ones of the sub-basin of Gölovası SGS are little higher than those of Afyon SGS. As it is expected the slopes get higher towards upstreams of rivers and consequently surface runoff parts of rainfall increases, which is seen here also.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

6.1 Discussion of the Results

The main channel slope and the mean basin slope are found to be the most important parameters individually for seasonal and annual runoff coefficients of the whole region. The main channel slope is a dominant factor on winter, spring and annual runoff coefficients; the mean basin slope has major impact on summer and fall runoff coefficients. When the basin width, the basin shape index (SI1) and the main channel length parameters are added to the main channel slope as a second parameter, the R-sq (adj) value does not increase so much. The basin parameters do not explain seasonal and annual runoff coefficients sufficiently in the whole region.

For Gediz Basin, the main channel slope and the mean basin slope are the most important parameters for seasonal and annual runoff coefficients. If the basin slope is high, then the rainfall becomes runoff quickly. Infiltration decreases as the slope increases, and the amount of the surface flow gets larger. While the mean basin slope, the total river length and the bifurcation ratio have high the R-sq (adj) value for fall runoff coefficient, only the main channel slope has high the R-sq (adj) value for winter runoff coefficient (Table 6.1). The total river length of basin is an important parameter due to water potential. The larger the total river length, the larger amount of runoff observed at the outlet of the basin. The bifurcation ratio can be accepted as a shape index, giving information about the shape of the basin and as a result about hydrograph shape. When the value of the bifurcation ratio of the basin is small, then the hydrograph will peak early. For summer runoff coefficient, the mean basin slope and the basin shape index (SI2) are together the most significant parameters. The shape of the basin has a dominant impact on the hydrograph shape and on the peak flow rate observed at the outlet of the basin. The shape of the basin has also effect on the time of concentration. The time of concentration increases as the basin area increases. The main channel slope and the drainage density are together important parameters with 88.37% and 91.39% the R-sq (adj) values for spring and annual runoff coefficients, respectively (Table 6.1). Snow is a major source of streamflow. In Western Anatolia, the snowmelt does not affect streamflow as well as in eastern Anatolia. Snowmelt usually begins in the spring and ends in the early summer. Drainage density has an important role on runoff coefficient. The larger the drainage density, the quicker the precipitation (including rainfall and also snowmelt) reaches to the stream. The sub-basin of Acısu SGS on Gediz River contains the sub-basin of Sazköy SGS on Murat Stream. The runoff coefficients of the sub-basin of Acısu SGS have higher values than the sub-basin of Sazköy SGS. Because the main channel slope of the sub-basin of Sazköy SGS is 24.7, that of sub-basin of Acısu SGS is 7.1.

Table 6.1 Largest R-sq (adj) values (%) of regression analyses for Gediz Basin.

GEDİZ BASIN Parameter(s)	Annual	Fall	Winter	Spring	Summer
MCS	82.25		83.99	80.99	
S		62.85			72.07
MCS, Dd	91.39			88.37	
S, MCL		76.73			
S, SI2					85.15
S, TRL, Rb		81.29			

For Büyük Menderes Basin, while the mean basin slope has weak (26.58%) R-sq (adj) value, the main channel slope and the drainage frequency have together moderately high (60.82%) the R-sq (adj) value, for fall runoff coefficient. The mean basin slope, the drainage frequency and the basin shape index (SI1) have together the greatest R-sq (adj) value with 48.21% for summer runoff coefficient (Table 6.2). These results show that, basin parameters do not explain the summer runoff coefficient as highly as the other seasonal and annual runoff coefficients. There may be other parameters, which affect the fall and the summer runoff coefficient, such as infiltration capacity, initial soil conditions and vegetal cover, which were not included in the analyses. The winter runoff coefficients have similarly same R-sq (adj) values with 83.42% (Rb, MCS, SI1) and 83.99% (MCS) for Büyük Menderes and Gediz Basins, respectively. The basin width is an individually important parameter with 65.55% R-sq (adj) value for spring runoff coefficient (Table 6.2). This parameter is a function of basin area and basin length. If the basin width is large, then the runoff coefficient takes larger value. The basin with, the Gravelius index (K_c) and the main channel slope have together high (86.41%) R-sq (adj) value. Similarly, the mean basin slope, the stream order of basin, the basin shape index and the drainage frequency have high (86.49%) R-sq (adj) value (Table A.5). The stream order and drainage frequency are related with the number of stream branches. In this study, Strahler method was used to determine the stream order of the basin. The annual runoff coefficient of Büyük Menderes Basin, the main channel slope, the bifurcation ratio and drainage frequency are together significant with high (84.26%) R-sq (adj) value (Table 6.2). The results revealed that the annual runoff coefficient of Gediz Basin is explained better with basin parameters than the annual runoff coefficient of Büyük Menderes Basin.

Table 6.2 Largest R-sq (adj) values (%) of regression analyses for Büyük Menderes Basin.

BÜYÜK MENDERES BASIN Parameter(s)	Annual	Fall	Winter	Spring	Summer
MCS	64.86				
S		26.58			13.69
Rb			57.83		
W_h				65.55	
Rb, MCS	78.24		77.83	79.7	
MCS, Df		60.82			
S, Df					27.52
Rb, MCS, Df	84.26				
Rb, MCS, SI1			83.42		
W_h, K_c, MCS				86.41	
S, Df, SI1					48.21

For Susurluk Basin, generally the drainage density, frequency and the mean basin slope are dominant parameters affecting the seasonal and annual runoff coefficients. Results show that there is not any statistically significant relation between basin parameters and the winter runoff coefficient. The drainage density and frequency have together impact on the fall runoff coefficient with moderate (63.93%) R-sq (adj) value. For spring runoff coefficient, the most important parameter is the mean basin slope with moderate (50.23%) R-sq (adj) value. The drainage frequency seems to be the major parameter for annual and summer runoff coefficients (Table 6.3). If the drainage frequency increases, the larger amount of runoff is observed at the outlet of the basin. The sub-basin of Geçitköy SGS on Nilüfer Stream has the highest spring runoff coefficient value with 0.95. Uludağ is located between middle and southeast of the sub-basin. It is the highest mountain of the Marmara region. Snowmelt is a major component of streamflow here beginning in the spring. Consequently, spring runoff coefficient of this sub-basin has the highest R-sq (adj) value due to snowmelt.

Table 6.3 Largest R-sq (adj) values (%) of regression analyses for Susurluk Basin.

SUSURLUK BASIN Parameter(s)	Annual	Fall	Winter	Spring	Summer
Df	32.83				52.64
Dd		51.23			
S				50.23	
Dd, Df		63.93			

For West Mediterranean Basin, basin shape index (SI1), bifurcation ratio and mean basin slope are the significant parameters. The basin shape index (SI1) has individually dominant impact on winter, annual and fall runoff coefficients. For spring runoff coefficient, the bifurcation ratio gives moderately high R-sq (adj) value. But, the basin shape index (SI1) and the mean basin slope together give the highest R-sq (adj) value (Table 6.4).

Table 6.4 Largest R-sq (adj) values (%) of regression analyses for West Mediterranean Basin.

WEST MEDITERRANEAN BASIN Parameter(s)	Annual	Fall	Winter	Spring	Summer
SI1	60.54	74.68	44.64		
Rb				67.95	
SI1, S				97.93	

For Aegean Basin, there are only four sub-basins used in the analyses. The combinations of drainage density with two parameters as basin width and bifurcation ratio give maximum percentage of R-sq (adj) values as 99.72% and 100%, respectively (Table 6.5). But there is not statistically significant relation between the basin parameters and fall, winter and summer runoff coefficients. The sub-basin of Yağcılı SGS has a very small area as 95.67 km^2, which is located upstream of the sub-basin of Eğrigöl SGS on Bakırçay Stream. The annual runoff coefficient of Yağcılı sub-basin is twice that of the sub-basin of Eğrigöl SGS. Because the main channel slope of this small sub-basin is 20.88, while it is 3.22 for the sub-basin of Eğrigöl SGS.

Table 6.5 Largest R-sq (adj) values (%) of regression analyses for Aegean Basin.

AEGEAN BASIN Parameter(s)	Annual	Fall	Winter	Spring	Summer
Dd	72.85			66.54	
Dd, Rb	100.00				
Dd, W_h				99.72	

The results explained above revealed that the basin parameters do not highly explain runoff coefficients not only for Susurluk Basin but also for winter and annual runoff coefficients of West Mediterranean Basin. Because of that, there should be other parameters, which affect the runoff coefficient. They may be infiltration capacity, vegetal cover and initial soil conditions.

6.2 Conclusions

In this study, monthly, seasonal and annual runoff coefficients of some basins in western and south-western part of Anatolia are determined. Their temporal and spatial distributions are investigated. The relationship between the basin parameters and the runoff coefficient are also examined. For these purposes, synchronous and average of long years data, which were measured at stream gauging stations (SGS) and precipitation observation stations (POS), are used for calculating monthly, seasonal and annual runoff coefficients of 48 sub-basins in the region.

Stream network delineation and basin boundary determination are made by using GIS techniques and by taking stream gauging stations as outlet points of the basins. Then the characteristics of the basin are similarly determined.

There are 14 sub-basins, which are generally located in south-western and south of Turkey, with runoff coefficient values greater than 1.0 for some months, seasons and also as annual value. Some of them are located at the upstream parts of basins. So these basins are not included in the average runoff coefficient calculations. There may be some reasons for having high runoff coefficients. Firstly, groundwater may feed the streams. Secondly, POSs may not represent the distribution of rainfall in the sub-basin sufficiently because of their locations. Thirdly, there are some dams for irrigation purposes in the study area, which affect the natural flows.

Annual average runoff coefficient value is 0.27 on the whole study area. It is smaller than the constant value used for Turkey. October and November coefficients are the smallest with a 0.13 value, while February coefficient is the largest as 0.39 among all months. The smallest seasonal average runoff coefficient value is for fall as 0.15, and the largest one is for spring as 0.34. Summer and winter runoff coefficients are equal to each other being 0.29. Consequently, except February, all monthly and seasonal runoff coefficients are smaller than the average value used for Turkey.

The large runoff coefficient values are generally obtained from Antalya Basin, south-western part of Turkey, some upstream basins (such as Sazköy sub-basin), Geçitköy sub-basin in north part of study region. The small ones are obtained from Selçuk sub-basin in Küçük Menderes, most of sub-basins in Büyük Menderes, Afyon Closed Basins and Çatallar sub-basin in south-western part of Anatolia. They are located at the middle part of the study region except Çatallar sub-basin. The runoff coefficient values are higher at north and south parts of the study region.

The analyses reveal that the R-sq (adj) values for annual and seasonal runoff coefficients of whole study area are not high. But the results of analyses give high R-sq (adj) values for some basin. Küçük Menderes and Afyon Closed Basins were not examined by regression analyses because of not having enough data. Küçük Menderes Basin has only one sub-basin and Afyon Closed Basin has two sub-basins. But the basin parameters and the runoff coefficients of these sub-basins were used in the regression analyses for the whole study area.

There are a number of dams in the region, which affect the natural flow. So, such streams were found and their sub-basins were not used in the analyses. The significant of some parameters increase such as SI1 for annual, winter runoff coefficients in West Mediterranean Basin and S for fall, summer runoff coefficient in Gediz Basin, while the importance of other parameters decrease such as MCS for spring and winter runoff coefficients in Gediz Basin. For some seasonal runoff coefficient of basins, the significant parameters change completely change such as TNB becomes important as a single parameter for summer runoff coefficient, while Df is found important for same season in Susurluk Basin in the analysis, which includes dams effect.

6.3 Recommendations

Following recommendations can be useful for similar and further studies.

1. The precipitation and the discharge data are obtained from State Meteorological Organization (SMO), and EİE, respectively. These data can be used in similar and further studies.

2. In this thesis, precipitation data of only SMO are used. To obtain better areal mean precipitation values, the precipitation data of State Hydraulic Works (SHW) should also be collected.

3. SRTM30 DEM is used for extracting stream network delineation, forming borders of basins and determining the basin parameters. A higher resolution DEM than SRTM30 DEM can give more detailed information for small basins.

4. For whole study area, the regression analyses results do not give high R-sq (adj) values. It is concluded that the basin parameters used in the study are not sufficient for explaining seasonal and annual runoff coefficients of this region. Soil condition, infiltration capacity, vegetal cover, land use and land cover are other effective parameters on the runoff coefficient. For further studies, they may be added as predictors in the regression analyses.

5. In this thesis, the relations between the basin parameters and the runoff coefficient are examined for a certain part of Anatolia. Similar studies can be performed for other parts of Turkey.

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APPENDIX

R-SQ (ADJ) VALUES OF REGRESSION ANALYSES

Table A. 1 R-sq (adj) values (%) of regression analyses for Susurluk Basin.

SUSURLUK BASIN Parameter(s)	Fall	Winter	Spring	Summer	Annual
Df			49.45	52.64	32.83
S			50.23		23.71
Dd	51.23				
Dd, Df	63.93				

Table A. 2 R-sq (adj) values (%) of regression analyses for Aegean Basin.

AEGEAN BASIN Parameter(s)	Fall	Winter	Spring	Summer	Annual
Dd			66.54		72.85
P, Dd					98.99
Dd, L_h					99.94
Dd, MCS					99.99
Dd, SO					99.75
Dd, TNB					99.99
Dd,Rb					100.00
Dd, W_h			99.72		

Table A. 3 R-sq (adj) values (%) of regression analyses for West Mediterranean Basin.

WEST MEDITERRANEAN BASIN Parameter(s)	Fall	Winter	Spring	Summer	Annual
SI1	74.68	44.64	61.30		60.54
Rb			67.95		
SI1, S			97.93		

Table A. 4 R-sq (adj) values (%) of regression analyses for Gediz Basin.

GEDİZ BASIN Parameter(s)	Fall	Winter	Spring	Summer	Annual
P					32.94
A					54.63
TRL					41.47
MCL					40.08
L_h					30.28
W_h		58.03			49.62
MCS	26.24	83.99	80.99	17.91	82.25
SO					32.47
TNB					33.13
SI2					21.59
K_c					23.20
S	62.85	36.23	75.53	72.07	74.47
Rb		56.53			55.03
MCS, Dd	51.11		88.37		91.39
TNB, Df					44.95
Rb, Df		78.10			67.97
Rb, S			82.76		82.65
S, A	73.89			80.99	
S, Dd	73.66				
S, TRL	75.00			82.74	
S, L_h	75.19			81.79	
S, MCL	76.73			82.39	
S, W_h			82.34		
S, SO			80.29	80.36	
S, P				83.45	
S, SI2				85.15	
S, K_c				85.07	
S, TNB				78.72	
Rb, Df, Dd					79.54
S, A, Rb	79.11				
MCS, Dd, P	67.45				
S, Dd, SI1	79.37				
S, TRL, Rb	81.29				
MCS, Dd, L_h	61.37				
S, L_h, Dd	80.55				
MCS, Dd, SI2	79.36				
S, Dd, SI2	80.85				
MCS, Dd, K_c	78.72				
S, Dd, K_c	80.63				
S, L_h, Dd, Rb	86.50				
S, Dd, SI2, Rb	88.99				
S, Dd, K_c, Rb	88.56				
S, Dd, K_c, Rb, Df	92.34				

Table A. 5 R-sq (adj) values (%) of regression analyses for Büyük Menderes Basin.

BÜYÜK MENDERES BASIN Parameter(s)	Fall	Winter	Spring	Summer	Annual
P					31.10
A			58.51		44.67
TRL			53.01		36.09
MCL					30.50
L_h					28.52
W_h		54.58	65.55		42.86
MCS		53.72	62.38		64.86
SO		48.51	55.49		43.60
TNB		50.45	59.09		52.01
S	26.58			13.69	56.77
Rb		57.83	51.32		46.14
Df	22.96				
A, SI1			71.51		51.41
A, Df					51.51
TRL, Df					45.47
L_h,SI1					41.07
L_h, Df					37.88
MCS, SI1		67.47			72.42
MCS, Dd					69.28
MCS, Df	60.82				75.20
MCS, Rb		77.83	79.70		78.24
S, TNB					62.46
MCL, SI1					38.64
MCL, Df					38.76
S, Rb		67.88	60.98		65.67
S, Df	57.50			27.52	
W_h, SI2		64.65	71.10		
W_h, K_c		64.23	70.90		
SO, S		56.08			
TNB, SI1		61.41	64.41		
TRL, SI1			68.61		
W_h, MCS			73.95		
MCS, SO			70.19		
MCS, SI1, SO		79.86	82.81		76.78
MCS, Rb, Dd					82.40
MCS, Dd, SO					73.84
MCS, Rb, Df					84.26
MCS, Rb, TRL					81.22
Rb, MCS, SI1		83.42			
W_h, SI2, MCS		79.63	86.21		
W_h, K_c, MCS		79.65	86.41		
SO, S, SI1		64.40			
TNB, SI1, Df		70.81	75.06		
W_h, MCS, SI1			84.91		
S, Df, SI1				48.21	
SO, S, SI1, Dd		73.01			
TNB, SI1, Df, S		75.23			
MCS, SO, SI1, Df			86.49		

Table A. 6 R-sq (adj) values (%) of regression analyses for the sub-basins in Susurluk Basin, which are not affected by dams or groundwater input.

SUSURLUK BASIN Parameter(s)	Fall	Winter	Spring	Summer	Annual
Dd	69.89				
Df			50.54	45.87	
MCS				47.52	
TNB				66.10	
MCL		42.30			
Df, MCS			84.54		
Df, MCS, SI2			98.92		
Df, MCS, K_c			98.61		

Table A. 7 R-sq (adj) values (%) of regression analyses for the sub-basins in Gediz Basin, which are not affected by dams or groundwater input.

GEDİZ BASIN Parameter(s)	Fall	Winter	Spring	Summer	Annual
A		51.83			
P		55.20			
Rb		51.58			
W_h		61.44			
S	71.73	38.84	80.29	81.50	75.52
MCS	48.54	82.15	79.18	35.96	83.02
TRL				42.05	
L_h				50.98	
MCL		51.84		46.72	
S, Dd	81.65				
S, Rb					81.55
MCS, Dd	74.28		86.96		92.97
Rb, Df		75.81			
S, SI1		54.34			
Rb, Df, TRL		86.48			
Rb, Df, TRL, S		91.98			

Table A. 8 R-sq (adj) values (%) of regression analyses for the sub-basins in Büyük Menderes Basin, which are not affected by dams or groundwater input.

BÜYÜK MENDERES BASIN Parameter(s)	Fall	Winter	Spring	Summer	Annual
S	70.91	38.93		77.75	51.66
MCS		52.96	62.81		55.42
W_h	53.38	53.62	45.12		60.34
SO	64.17	46.51		24.61	54.42
Df	35.93				
TNB			26.11		
MCS, Rb		82.10			80.97
MCS, SI1		71.21	78.93		75.50
S, Df	85.23				
Df, MCS	68.29				
MCS, P			81.24		
MCS, TRL			84.73		
MCS, L_h			90.37		
MCS, MCL			85.28		
MCS, P, SI1			93.37		
MCS, TRL, Rb			94.15		
MCS, SI1, Df			88.08		
MCS, SI1, W_h			92.32		

Table A. 9 R-sq (adj) values (%) of regression analyses for the sub-basins in West Mediterranean Basin, which are not affected by dams or groundwater input.

WEST MEDITERRANEAN BASIN Parameter(s)	Fall	Winter	Spring	Summer	Annual
SI1		81.14	61.30		63.45
Rb			67.95		
SI1, SI2					99.73
SI1, K_c					99.75
SI1, S			97.93		

Table A. 10 R-sq (adj) values (%) of regression analyses for the whole study area.

Parameter (s)	Winter	Spring	Summer	Fall	Annual
P	14.53	21.17			11.05
A	16.74	24.13			13.22
TRL	16.13	22.73			11.74
MCL	9.64	15.01			6.17
L_h	10.71	16.95			6.91
W_h	21.73	26.54			16.99
MCS	23.56	29.41	16.56	28.95	35.76
SO	12.71	22.48			13.16
TNB	16.38	25.1			14.32
SI2		7.19	3.11		
S	6.08	7.49	22.23	29.12	19.83
K_c		7.06	3.32		
Rb	6.69	12.96	5.52	4.48	13.99
P, SI1					17.83
P, S	19.71	27.61			29.71
A, SI1					18.48
A, S	21.6	30.06			31.27
TRL, SI1					17.67
TRL, S	21.22	29.15			30.26
L_h, SI1	18.05				17.13
L_h, S		23.45			26.2
W_h, S	27.03	33.7			34.83
MCS, SI1					39.91
MCS, Dd				31.92	38.87
SO, SI1					15.78
SO, S	15.87	25.41			27.68
TNB, SI1					18.42
TNB, S	20.25	29.48			30.67
SI1, MCL					12.9
S, MCL	15.36	22.11			25.92
S, Rb	9.59				26.04
MCS, TRL		31.62	21.73	37.12	
MCS, W_h	28.68	35.21	25.95	35.99	
MCS, L_h				34.61	
MCS, K_c				35.06	
MCS, MCL			20	37.92	
MCS, SI2				34.85	
MCS, SO			20.16	36.11	
MCS, P			21.16	36.45	
P, SI1, S	22.86	30.48			34.51
A, SI1, S					34.84
TRL, SI1, S	23.91	31.4			34.39
L_h, SI1, S	22.87	29.96			33.74
TNB, SI1, S					33.22
SI1, MCL, S					30.76
MCS, W_h, SI2	33.17			37.74	
MCS, W_h, K_c	33.39			37.91	
MCS, P, SI1			23.96		

Table A. 10 (cont'd) R-sq (adj) values (%) of regression analyses for the whole study area.

Parameter (s)	Winter	Spring	Summer	Fall	Annual
MCS, TRL, SI1		33.96	24.17		
MCS, MCL, SI1			23.54		
MCL, S, SI1	19.01	25.19			
MCS, W_h, Dd	31.41				