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## Analyzing Variation of Sediment Yields in Wet and Drought Years

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### ABSTRACT

This study presents meteorological and hydrologic drought effects on sediment yield in a small rural basin, Uğrak Watershed in Tokat Region of North Central Anatolia, Turkey. Sediment yield was estimated by using Modified Universal Soil Loss Equation (MUSLE) model for 25 years period. The maximum and minimum sediment yields were estimated in 1980 and 1997 respectively. Historical precipitation and flow data were analyzed to determine meteorological and hydrological drought by Standardized Precipitation Index (SPI) method. Results showed that there was 10-year drought vs. 15-year wet for meteorological and 14-year drought vs. 11-year wet for hydrological conditions. In the meteorologically drought and wet years, the sediment yields were estimated as 6920.7 tons and 18068.2 tons, respectively. In the hydrological dry and wet years, the sediment yields were estimated as 7417.8 tons and 21489.2 tons, respectively. Sediment yields were found similar in meteorological and hydrological wet and also similar in meteorological and hydrological dry conditions. Drought reduced the sediment yield in the study area.

Keywords: MUSLE; GIS; Drought; Sediment yield; Watershed

## Yağışlı ve Kurak Yıllarda Sediment Veriminin Değişim Analizi

### ESER BİLGİSİ

Araştırma Makalesi—Doğal Kaynak Yönetimi ve Peyzaj Planlama

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### ÖZET

Bu çalışma meteorolojik ve hidrolojik kuraklığın küçük bir kırsal havzada, Kuzey Orta Anadolu Bölgesi Tokat İli Uğrak Havzası, sediment verimi üzerine etkilerini incelemek amacıyla yürütülmüştür. Sediment verimi Modifiye Ünlversal Toprak Kaybı Eşitliği (MUSLE) denklemi kullanılarak 25 yıllık bir dönem için tahmin edilmiştir. En fazla ve en az sediment verimi sırasıyla 1980 ve 1997 yıllarında hesaplanmıştır. Meteorolojik ve hidrolojik kuraklık, tarihsel yağış ve akış verileri kullanılarak Standardize Edilmiş Yağış İndeksi (SPI) ile tespit edilmiştir. Çalışma süresinin 10 yılı meteorolojik olarak kurak ve 15 yılı yağışlı geçerken, hidrolojik olarak 14 yılı kurak, 11 yılı yağışlı geçmiştir. Meteorolojik olarak kurak ve yağışlı yıllarda sediment verimi sırasıyla 6920.7 ton ve 18068.2 ton olarak hesaplanmıştır. Hidrolojik olarak kurak ve yağışlı yıllarda sediment verimi sırasıyla 7417.8 ton ve 21489.2 ton olarak hesaplanmıştır. Hesaplanan sediment verimi, meteorolojik ve hidrolojik yağışlı ve aynı zamanda meteorolojik ve hidrolojik kurak şartlar altında benzer bulunmuştur. Kuraklık, çalışma alanındaki sediment verimini düşürmüştür.

Anahtar Kelimeler: MUSLE; CBS; Kuraklık; Sediment verimi; Havza

## 1. Introduction

Drought and wet conditions may affect the sediment amount. The suspended sediment loads in a stream are the results of erosion and transportation process. Sediment yield might increase or decrease during drought seasons. Drought influences erosion primarily through changes in the amount and intensity of rainfall, which associated with reduction of cover vegetation (Schumm 1977). These two factors describe the erosion response to drought. The reduction of rainfall during dry season reduces the erosion; moreover it reduces cover vegetation and the landscape becomes more vulnerable to erosion.

In order to understand which is the most controlling factor on sedimentation in drought condition, several studies has been conducted. Giakoumakis & Tsakiris (1997) used continuous simulation model with the reconnaissance estimation of sediment yield from a hydrological basin to describe drought effect on sediment yield. In their study, sediment yield estimations were found higher during the wet period following a drought period. Pruski & Nearing (2002) used WEPP model to find a relation between changes of precipitation and their significant implications on runoff, soil erosion, and conservation planning. In this study, erosion increased approximately 1.7% for each 1% change in annual rainfall. Rainfall amounts and intensities were found as the most direct and important factor on changes of erosion under various climate. Nearing et al (2005) investigated the response of seven soil erosion models using a few basic precipitation and vegetation data under humid and semiarid watersheds. They indicated that soil erosion is likely to be more affected by rainfall and cover vegetation than runoff, though both are likely impacted in similar ways. Nunes et al (2008) conducted a research to estimate the effect of climate change on water resources, vegetation productivity and erosion. This was done by analyzing the sensitivity of these variables to varying degrees of temperature change, rainfall (reduced by up to 40%) and atmospheric CO<sub>2</sub> concentrations. The SWAT watershed model was applied to 18 large watersheds in two contrasting regions of Portugal (humid and semi-arid regions); incremental changes to climate variables were simulated using a stochastic weather generator. The main results indicated that, water runoff is highly sensitive to the trend of climate change. For the milder rainfall changes, soil erosion showed a significant increasing trend in the wheat fields (up to 150% in the humid watersheds). The common agreement of these studies is that the rainfall factor dominates and erosion tends to decrease with decreasing annual rainfall. This suggests that drought is associated with periods of low sediment yield. But the effects of drought on vegetation

and sedimentation are nonlinear. The results of numerous plot studies indicated that vegetative cover is the dominant factor controlling erosion, particularly during drought conditions (Dadkash & Gifford 1980; Wood et al 1987; Blackburn et al 1992; Gutierrez & Hernandez 1996). These studies indicate that the loss of cover vegetation leaves soils so vulnerable to erosion that even with decreases rainfall erosivity during drought seasons, erosion rates increase dramatically. However, it is not clear that drought effect on sediment yield at watershed scale due to watershed complexity.

Dodangeh et al (2011) conducted a research to consider for hydrological drought analysis at 26 selected stations out of 41 stream flow gauging stations located at the north of Iran. The study area was found heterogeneous and therefore Fuzzy Cluster Analysis (FCA) algorithm was applied to divide being homogenous subregions. Two regions were identified as the result of FCA analysis and the L-Moment analysis. One region was found homogenous and the Generalized Logistic (GLO) distribution was selected for this region. A study related to hydrological drought by using SPI were conducted in the southern Cordoba Province in Argentina to analyze the potential of the SPI as a tool for monitoring flood risk. This study indicated that the SPI satisfactorily explains the development of conditions leading up to the three main flood events to occur in the region during the past 25 years (Seiler et al 2002). The numerous studies in Turkey were used to describe drought with the help of SPI method (Yurekli & Kurunc 2006; Yurekli & Anlı 2008; Anlı et al 2009; Yurekli et al 2009; Yurekli et al 2010; Yurekli et al 2010; Yurekli et al 2012).

Information on the sediment yield at the outlet of a river basin is providing a useful perspective to predict the rates of erosion and soil loss in the watershed upstream. In many countries, such measurements were conducted in some research basins. These research activities needs time and costs. Some empirical equation or models produced from these studies, and these models give some advantages as time and costs. The empirical models are widely used for computing the amount of potential soil erosion and sediment yield. Empirical models such as USLE (Universal Soil Loss Equation), MUSLE (Modified Universal Soil Loss Equation) and RUSLE (Revised Universal Soil Loss Equation) provide useful information to predict sediment amount from outlet. Many researchers have conducted some research to evaluate the MUSLE under different conditions for different purposes around the world (Asokan 1981; Nicks et al 1994; Banasik & Walling 1996; Kinnel 2001; Erskine et al 2002; Sadeghi 2004; Cambazoglu & Gogus 2004; Mishra et al 2006; Sadeghi et al 2007; Pandey et al 2009).

Oğuz et al (2011) stated that the K value which is one of MUSLE equation factors is greatly influenced by land slope. In their study, to describe desertification potential in a rural watershed they compared some soil properties in two slope groups (mild to moderate and moderate to steep) with the help of coefficient of variation and fractal dimension of spatial variation. In the study, they found higher fractal coefficients in steep slopes than mild slope and high fractal coefficients values expected to be short-range variation. Generally higher CV values and lower D values occurred in moderate to steep slopes, indicating greater desertification potential.

Yurekli & Ozturk (2000) calculated erosion index of Uğrak watershed according to total kinetic energy from 1978 to 1998 years. Yearly erosive index values of the watershed varied between 0.40 and 24.16 MJ.cm/ha.h.

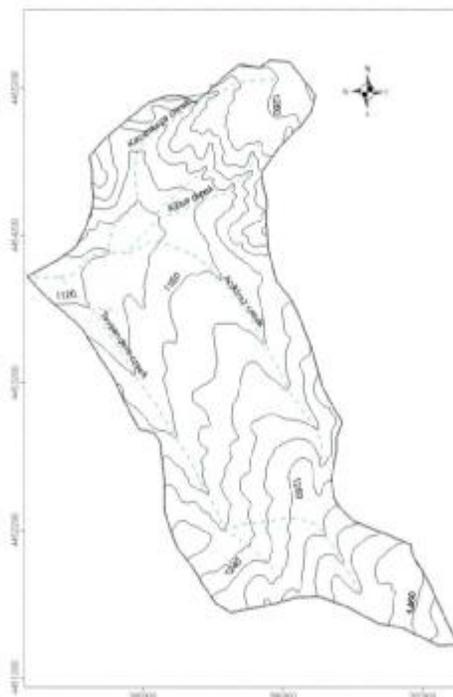
Uğrak watershed is a research basin and rainfall and runoff characteristics were investigated for 25 years period. The storm runoff volume and peak runoff parameters are required for MUSLE models and the mentioned parameters were directly obtained from research findings of the watershed.

In the present study, we investigated the effect of drought on sediment yield in a small agricultural watershed. The objective of this study is to compare the sediment yields in meteorological drought and hydrological drought conditions. This was done by history of meteorological and hydrological data and estimated sediment data by MUSLE.

## 2. Material and Methods

The present study took place at the Uğrak watershed in Tokat region of North Central Anatolia. The geographical area of the watershed is approximately 700 ha with an elevation ranging from 1292.5 to 1485.0 m above mean sea level (Figure 1). Some of the other geometric characteristics of the catchment area are as listed in Table 1. The average rainfall is 483.6 mm and minimum and maximum temperature is varying from -3.3 to 17.8°C. The overall climate of the area is semi-arid. The soils, Entisols and Inceptisols are moderate to well-drained. The watershed contains mild to moderate steep areas with low vegetation densities and/or under cultivation. The areas with <12% slopes are mainly cultivated. The major vegetation type in fallow areas is grassland with *Graminea* and *Fabaceae* as dominant species, other types being shrubs and meadows. The cultivated areas are relatively large, covering 76.6% of the catchment and the wheat - fallow rotation is common. Some woodland, mostly shrubs with a few trees, covering approximately 6.2% of the catchment, are scattered about. The natural

grassland mostly degraded due to heavy grazing, covers 17.2% of the area. Daily rainfall and runoff data of the watershed were collected from the three automatic rain-gauge stations and stream flow gauging station located at the outlet of the study watershed bridge between from 1978 and 2002.



**Figure 1- General feature and topographical map of Uğrak watershed**

*Şekil 1-Uğrak havzasının genel özellik ve topografik haritası*

**Table 1- Some of the geometric characteristics of the Uğrak watershed**

*Çizelge 1- Uğrak havzası bazı şekil karakteristikleri*

Area, ha	700.0
Mean elevation, m	1292.5
The most top point elevation, m	1485.0
Outlet elevation above sea level, m	1100.0
Catchment perimeter, km	14.0
Average slope, %	20.6
Average slope of main river, %	4.7
Total length of the river, km	18.2
Length of the main river, km	6.7

### 2.1. Sediment Yield Prediction (MUSLE)

The MUSLE was developed from USLE by replacing the rainfall energy factor (R factor) with a runoff energy factor. The equation was developed using

individual storm data from 18 basins in Texas and Nebraska and subsequently validated on 102 basins throughout the United States using runoff data generated by the hydrologic component of the SWRRB (Simulator for Water Resources in Rural Basins) model (Williams 1982). The MUSLE increases sediment yield prediction accuracy, eliminates the need for sediment delivery ratios, and is applicable to individual storms. MUSLE is expressed by Williams & Berndt (1977) as:

$$Y = 11.8(Qqp)^{0.56}KLSCP \quad (1)$$

Where Y is the sediment yield from an individual storm in metric tons, Q is the storm runoff volume in  $m^3$ , qp is the peak runoff rate in  $m^3s^{-1}$ , and K is soil erodibility factor ( $t.h.t^{-1}m^{-1}$ ), LS is topographic factor (dimensionless), C is crop factors (dimensionless) and finally P is erosion control practice factor (dimensionless) similar to the USLE model (Williams & Berndt 1977). MUSLE is used to predict sediment yield on a single storm basis, but it can also be used to predict sediment yield on annual basis with Equation 2 (Simons & Senturk 1992; Cambazoglu & Gogus 2004).

$$As = \frac{Qa(0.01Ys100+0.01Ys50+0.02Ys25+0.06Ys10+0.4Ys2)}{0.01Qv100+0.01Qv50+0.02Qv25+0.06Qv10+0.4Qv2} \quad (2)$$

Where As is the annual sediment yield, and Qa is the average annual water yield, and Ys and Qv are single storm event sediment yield and water yield with corresponding return periods, respectively.

Soil erodibility factor was estimated using the Equation 3 given by Foster et al (1991).

$$100K = 2.1M^{1.14}10^{-4}(12 - a) + 3.25(b - 2) + 2.5(c - 3) \quad (3)$$

Where M [(silt + very fine sand)(100 - clay)] is particle size parameter, a is percent organic matter, b is soil structure code and c is soil permeability class.

The slope length factor (L) was calculated with the help of Equation 4 (Mc Cool et al 1987).

$$L = (\lambda/22.1)^m \quad (4)$$

Where L is slope length factor, which is field slope length (m), m is a coefficient that depends on slope steepness, being 0.5 for slopes exceeding 5%, 0.4 for 4% slopes and 0.3 for slopes less than 3%. The percent slope was determined from DEM with the help of Equation 5.

$$S = 10.8\sin\theta + 0.03 \quad s < 9\%, \quad S = 16.8\sin\theta - 0.05 \quad s \geq 9\% \quad (5)$$

Where s is slope steepness factor and  $\theta$  is slope angle in degree.

The cover and management factor (C factor) represents a combined effect of interrelated cover and management variables. C values derived from local research findings for each land use. The support practice factor (P factor) represents a combined effect of support practices and management variables. They are also known as structural methods for controlling

erosion. In an area, if conservation practices are not followed P value should assign as 1.

## 2.2. The Method of L-Moments

To obtain the sediment and water yield with corresponding return periods in the watershed, we used the distributions of Normal, 2-parameter Log-Normal, Extreme Value Type I, Generalized Logistic, Generalized Pareto, Generalized Extreme Value, 3-parameter Log Normal. The parameter estimation of the distributions taken into account in the study was obtained from L-moment approach as defined by Hosking and Wallis (1997). L-moments are linear combinations of probability weighted moments (PWM). Greenwood et al (1979) summarizes the theory of PWM and defined as;

$$\beta_r = E\{X[F_X(X)]^r\} \quad (6)$$

Where  $\beta_r$  is the  $r^{\text{th}}$  order PWM and  $F_X(X)$  is the cumulative distribution function (cdf) of Hosking & Wallis (1997) defined unbiased sample estimators of PWMs as ( $b_i$ ) and, obtained unbiased sample estimators of the first four L-moments by PWM sample estimators. Unbiased sample estimates of the PWM for any distribution can be computed from;

$$b_r = n^{-1} \sum_{j=1}^{n-r} \frac{\binom{n-j}{r}}{\binom{n-1}{r}} X_j \quad (7)$$

Where  $X_j$  is an ordered set of observations  $x_1 \leq x_2 \leq x_3 \leq \dots x_n$ . For any distribution the first four L-moments are easily computed from PWM using;

$$\begin{aligned} \lambda_1 &= b_1 & \lambda_2 &= 2b_2 - b_1 \\ \lambda_3 &= 6b_3 - 6b_2 + b_1 \\ \lambda_4 &= 20b_4 - 30b_3 + 12b_2 - b_1 \end{aligned} \quad (8)$$

Sankarasubramanian & Srinivasan (1999) defines the L-moment ratios (L-coefficient of variation, L-skewness and L-kurtosis, respectively)

$$\tau_2 = \frac{\lambda_2}{\lambda_1}, \quad \tau_3 = \frac{\lambda_3}{\lambda_2}, \quad \tau_4 = \frac{\lambda_4}{\lambda_2} \quad (9)$$

The goodness-of-fit-test based on the Kolmogorov-Smirnov approach given in Haan (1977) was used to select the best distribution fit to the sediment and water yield data.

## 2.3. Standardized Precipitation Index (SPI) Algorithm

In our study, the Standardized Precipitation Index (SPI) approach was used to determine sediment yield in wet and drought periods. The SPI developed by McKee et al (1993) is a way of measuring drought based only on precipitation. Although the SPI approach was originally developed to monitor drought from precipitation, but in the study the SPI was used in predicting wet and drought periods based on both precipitation and stream flow. The SPI are used to monitor conditions on a

variety of time scales. Technically, the SPI is the number of standard deviations that the observed value would deviate from the long-term mean, for a normally distributed random variable. The SPI have some advantages for the following reason. Precipitation is only variable in the SPI calculation. Therefore, this index can be applied in regions where the availability of climatic variables limits the use of other well-accepted indices as Palmer Drought Index (PDSI). SPI, which has a wide spectrum of time scales, make this index more flexible for both short-term and long-term drought monitoring (Edwards & McKee 1997). The SPI algorithm is conceptually equivalent to z-score commonly used in statistic:

$$SPI = \frac{P_i - \sum_{i=1}^n P_i / n}{\sigma_p} \quad (10)$$

Where  $SPI$  is represent the standardized precipitation index,  $P_i$  is rainfall for a given period,  $n$  is the total length of record and  $\sigma_p$  is standard deviation.

It is known that rainfall is typically positively skewed. Therefore, the precipitation data should be transformed a more normal or Gaussian symmetrical distribution to use the above z-score relationship (SPI). McKee et al (1993; 1995) and Komuscu (1999) implied that the long-term rainfall data sets must first be normalized to determine SPI belonging to the data sets. The prevalent conviction related to the transformation of monthly rainfall is that the gamma distribution is applied. Thorn (1966) stated that monthly rainfall generally fit to the gamma distribution. Guttman (1999) examined the impact of six distributions on SPI and recommended that Pearson Type III distribution is the best way to normalize long-term data when calculating SPI. Edwards and McKee (1997) suggested gamma distribution with two parameters to transform the precipitation data.

Sediment yields in meteorological and hydrological drought and wet conditions were compared using t-test.

### 3. Results and Discussion

For estimating of soil erodibility factor for each soil series, soil samples were taken from the topsoil. The calculated K values using the Equation 3 are presented in Table 2. In the study area, the calculated K values varied between 0.03 and 0.25 t.h.t<sup>-1</sup>m<sup>-1</sup>. The most dominated soil series were Tekneli and Tavşandere soil series, and their K factors were 0.03 and 0.25, respectively. The spatial distribution of soil erodibility values are given in Figure 2.

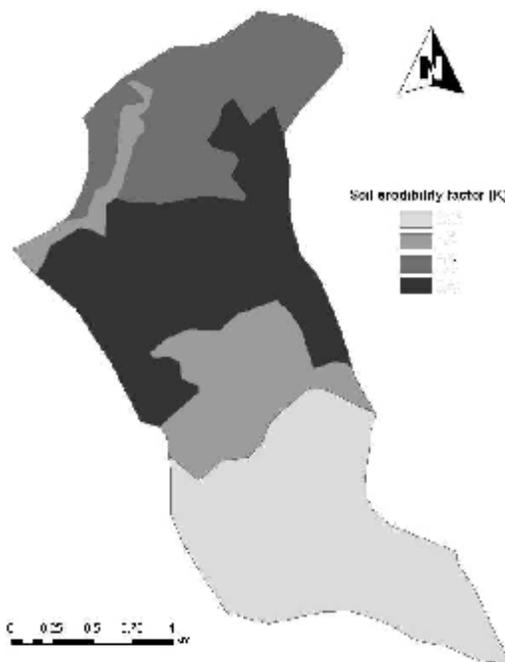
Topographic factor (LS) was derived from DEM by multiplying the L and S factors. An increase in LS values show that the increasing rate of soil erosion. The LS values in the Uğrak watershed varied between 0 and

8.5 and its spatial distribution was presented in Figure 3.

**Table 2- Soil erodibility factor for soil series**

*Çizelge 2- Toprak serileri aşınma duyarlılık faktörü*

Soil Series	Area		K Factor
	km <sup>2</sup>	%	
Tekneli	2.33	33.29	0.03
Semertas	1.36	19.43	0.21
Acikiraz	0.95	13.57	0.20
Tavşandere	2.15	30.71	0.25
Uğrak	0.21	3.00	0.20
Total	7.00	100.00	

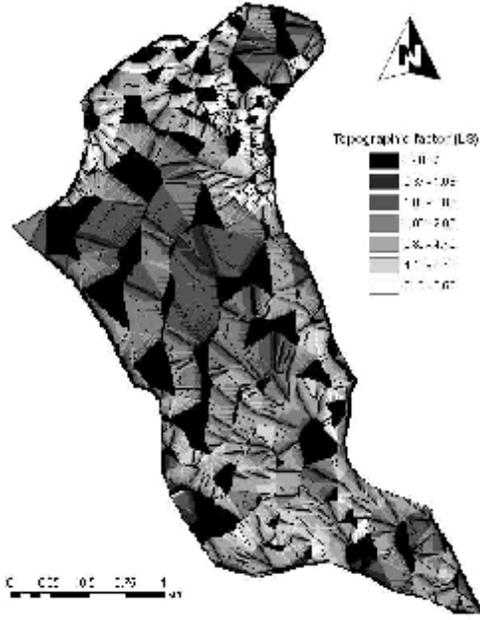


**Figure 2- Distribution of soil erodibility factor in the study watershed**

*Şekil 2-Çalışma havzası aşınma duyarlılık dağılımı*

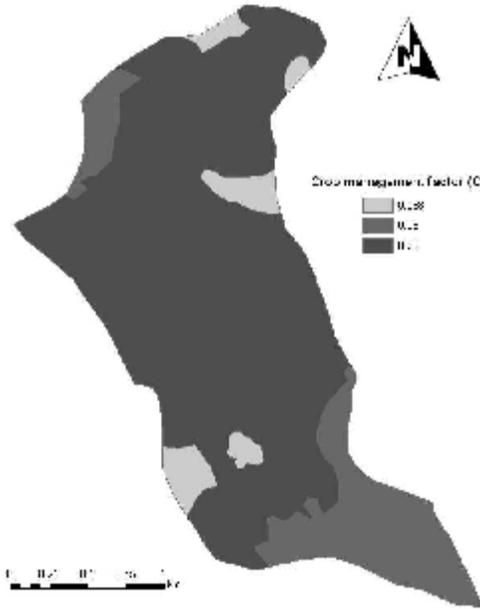
The factors of C were assigned to different land use types (Table 3) and were presented spatially in Figure 4. There are 3 main land use types as cropland, grassland and shrub in the Uğrak watershed. The crop management factors for cropland were obtained experimental plots (Oğuz et al 1998). On the other hand, the crop management factors for grassland and shrubs were used by previously proposed values of Çanga (1995).

In the study area, conservation practices are not followed. Hence, the conservation practice factor of 1 was assigned.



**Figure 3- Distribution of topographic factor in the study watershed**

Şekil 3-Çalışma havzası topoğrafik faktör dağılımı



**Figure 4- Distribution of crop management factor in the study watershed**

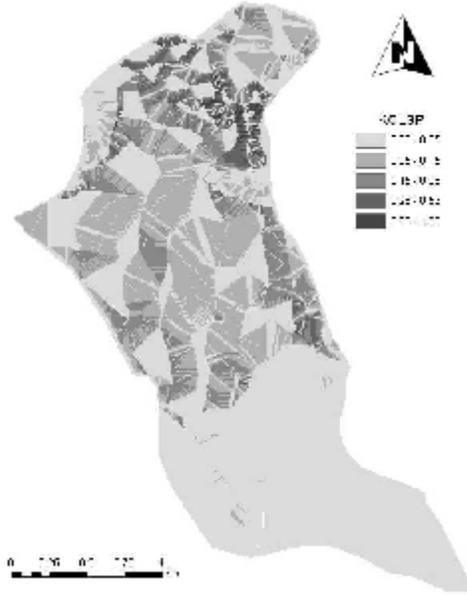
Şekil 4-Çalışma havzası bitki yönetim faktör dağılımı

**Table 3- Crop management factor for land use/land cover classes**

Çizelge 3- Arazi kullanım türlerine ait bitki yönetim faktörleri

Landuse	Area		C Factor
	km <sup>2</sup>	%	
Shrub	0.32	4.57	0.038
Grassland	1.22	17.43	0.050
Dry farming	5.46	78.00	0.280
Total	7.00	100.00	

Finally KLSCP values were multiplied in ArcGIS environment and the result is presented spatially in Figure 5. Average KLSCP value was found 0.07 and some statistical evaluations were given in Table 4. In order to calculate the sediment yield in Uğrak watershed by MUSLE, average KLSCP value was taken as 0.07.



**Figure 5- Distribution of multiplied KCLSP factors in the study watershed**

Şekil 5-Çalışma havzasında KCLSP factor çarpımlarının dağılımı

**Table 4- Statistical distribution of KLSCP values**

Çizelge 4- KLSCP değerlerinin istatistiksel dağılımı

Statistical parameters	Min	Max	Mean	STDV	CV, %
K	0.03	0.25	0.18	0.08	44.44
LS	0.00	8.50	1.90	2.00	105.26
C	0.038	0.28	1.90	2.00	105.26
KLSCP	0.00	1.38	0.07	0.10	142.86

The average long-term discharge of the Ugrak watershed was 55.64 mm/year. Fourteen storms, for which an accurate and a reported data were available, were selected in the present study and detailed information is shown in Table 5 (Oguz & Balcin 2003).

The selected storms of Uğrak watershed were used in applying Equation 1, and the results are presented in Table 5. The next step to predict annual sediment yield in the watershed were applied Equation 2. For this purpose the weighted storm yield was multiplied by the ratio of annual water yield to single storm sediment yield and water yield at some return periods (Table 6.). Table 6 is predicted from the Log-Normal distribution. The Log-Normal distribution among the distributions used in this study had the most minimum Kolmogorov-Smirnov test value than the other distributions. Therefore, the Log-Normal distribution was selected as best-fit distribution in order to obtain the sediment and

water yield with corresponding return periods. The computation of annual sediment yield after using MUSLE was presented in Table 7.

In this study, annual total rainfall and flow were used to determine meteorological and hydrological drought in the watershed. For this purpose we used Standardized Precipitation Index (SPI) to rainfall and flow between 1978-2002 years for 25 years period. In this period, 10 years drought and 15 years wet were found as meteorological and 14 years drought and 11 years wet were experienced as hydrological (Table 7). As rainfall and stream flow data were skewed, the mentioned data was transformed by taking logarithm of the data set. Thus, the rainfall and stream flow data were transformed a more normal or Gaussian symmetrical distribution to use the above z-score (SPI) relationship.

**Table 5- Selected storms and estimated sediment yield by MUSLE in Ugrak watershed**

*Çizelge 5- Uğrak havzası seçilmiş akımları ve MUSLE ile hesaplanmış sediment verimi*

No	Storm date	Rainfall		Runoff			Estimated sediment yield (ton)	
		Depth (mm)	Duration (h)	Volume (m <sup>3</sup> )	Peak flow, (m <sup>3</sup> s <sup>-1</sup> )	Duration (h)		
1	21.05.1979	14.6	1.42	1750	0.25	1.320	2.33	63.18
2	23.06.1979	24.9	1.83	4550	0.65	2.540	2.50	155.66
3	12.07.1979	19.1	0.67	2520	0.36	1.560	2.50	85.10
4	08.05.1980	10.6	3.71	3080	0.44	2.070	2.50	111.56
5	11.09.1981	16.2	0.5	1190	0.17	0.990	2.50	43.34
6	30.05.1983	11.1	0.58	3430	0.49	1.250	2.50	89.33
7	31.05.1983	8.5	1.92	980	0.14	0.740	1.83	33.02
8	16.05.1985	1.3	0.25	140	0.02	0.082	1.67	3.24
9	14.06.1986	14.5	2.08	4690	0.67	3.480	2.00	188.85
10	04.06.1989	3.6	0.42	420	0.06	0.280	1.83	11.92
11	09.07.1992	16.5	0.67	770	0.11	0.268	2.67	16.34
12	25.05.1993	14.8	3.25	840	0.12	0.286	4.17	17.79
13	07.10.1993	11	0.75	420	0.06	0.311	4.25	12.65
14	12.09.2002	19.9	0.75	980	0.14	0.416	3.00	23.92

**Table 6- Return periods for single storm sediment yield and water yield (for non-exceedance probability)**

*Çizelge 6- Sediment ve su verimi için bireysel fırtınaların tekrerrür süreleri (aşılmama olasılığına göre)*

Series	Return periods, years				
	2	10	25	50	100
Ys, ton	1775.66	537.98	347.48	261.99	203.22
Qv, m <sup>3</sup>	1230.04	319.99	195.46	142.16	106.75

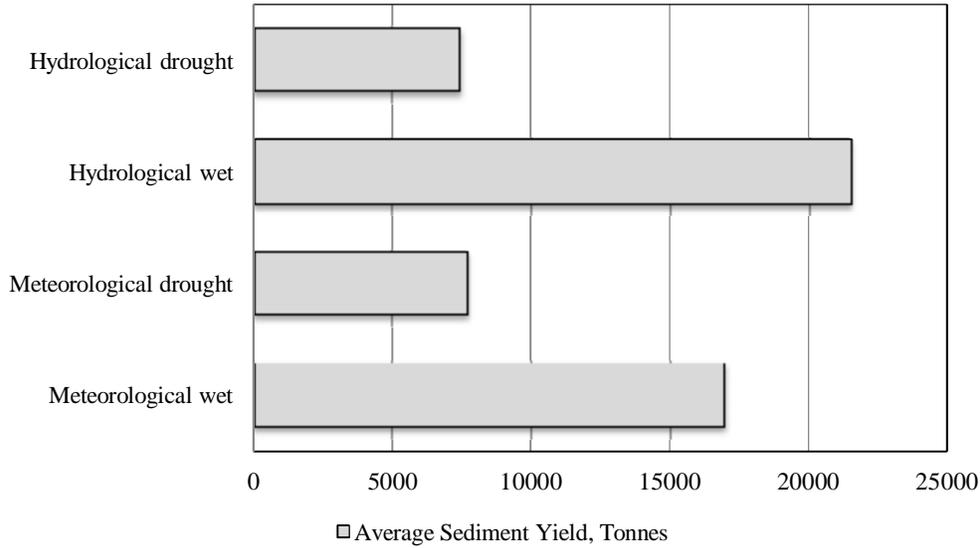
**Table 7- Rainfall, flow, runoff, sediment yield and SPI values in Ugrak watershed**  
*Çizelge 7- Uğrak havzasında yağış, akış, yüzey akış, sediment verimi ve SPI değerleri*

Years	Rainfall, (mm)	Flow, (m <sup>3</sup> )	Runoff, (m <sup>3</sup> )	Sediment yield (ton)	SPI Values	
					Rainfall	Flow
1978	481.5	184380	3220	4691.4	-0.026	-0.898
1979	518.5	116760	4008	5838.8	0.433	-1.194
1980	528.1	733880	19653	28633.0	0.551	1.509
1981	496.9	833490	11649	16972.4	0.165	1.945
1982	505.1	208810	2088	3042.6	0.267	-0.791
1983	378.3	626360	3582	5218.4	-1.304	1.038
1984	591.1	588910	9823	14312.2	1.332	0.874
1985	341	255850	6026	8779.4	-1.767	-0.585
1986	535.4	461860	3407	4963.4	0.642	0.317
1987	414.4	373800	134	195.5	-0.857	-0.069
1988	594.8	647220	13242	19292.6	1.378	1.129
1989	448	250880	6510	9484.8	-0.441	-0.607
1990	607.2	605290	19209	27987.1	1.531	0.945
1991	499.8	274820	7327	10674.7	0.201	-0.502
1992	514.5	314020	10074	14677.7	0.383	-0.330
1993	537.6	567210	31780	46302.3	0.669	0.779
1994	343.2	612290	18381	26780.2	-1.739	0.976
1995	546.3	650790	12851	18723.2	0.777	1.145
1996	554.4	258790	8814	12841.9	0.877	-0.572
1997	365.4	63910	117	170.0	-1.464	-1.426
1998	521.2	396970	18667	27196.7	0.466	0.033
1999	459	113820	1225	1784.8	-0.305	-1.207
2000	499.6	350000	13428	19564.6	0.198	-0.173
2001	328.3	14350	362	526.9	-1.924	-1.643
2002	480.1	231700	7945	11575.6	-0.043	-0.691

Estimated sediment yield by MUSLE were grouped meteorologically and hydrological drought and wet conditions in Figure 6. Sediment yields in meteorological and hydrological drought and wet conditions were compared using t-test and presented in Table 8. The estimated mean sediment yields were found similar in meteorological and hydrological wet conditions, whereas it was significantly different in meteorological and hydrological drought conditions. Changes in rainfall, erosion and as well as in the amount of cover vegetation result in further changes in both hydrology and soil erosion. These interactions

may not be accurately represented by watershed complexity.

Increasing precipitation and stream flow often result to increasing erosion as well as the amount of suspended sediment in a watershed. In Uğrak watershed we concluded that the drought decreases sediment yield dramatically. Same result was found in the Selenga River watershed within the Yenisey River watershed in southern East Siberia (Korytny et al 2003). In that study, an increase in precipitation was observed by an increase in suspended sediment load.



**Figure 6- Sediment yield in drought and wet periods in Uğrak watershed**  
 Şekil 6-Kurak ve yağışlı dönemlerde Uğrak havzası sediment verimi

**Table 8- Average estimated sediment yield of different drought conditions**

Çizelge 8- Farklı kuraklık koşullarında hesaplanmış ortalama sediment verimi

Drought	Average Estimated Sediment Yield (ton)
Meteorological drought	6921 <sup>b</sup>
Meteorological wet	18068 <sup>a</sup>
Hydrological drought	7418 <sup>b</sup>
Hydrological wet	21489 <sup>a</sup>

As contrast, at four watersheds, the Edwards Plateau Land Resource Area of Texas in USA, were combined with the results of three prior surveys to assess the effect of the 1950s drought on sediment yield (Dunbar et al 2010). It was concluded that drought increased sediment yield dramatically. This suggests that the reduction of cover vegetation during the drought period become the rangeland so vulnerable to erosion. This factor outweighed the reduction in rainfall erosivity. In Uğrak, watershed land use is mostly dry farming (Table 3). Limited perennial vegetation and limited reduction of cover vegetation had a limited effect on sediment yield at drought conditions in the watershed.

Because of having different watershed characteristics, drought effect on sediment yield is different for every watershed. Therefore, more studies should be done to determine the effect of drought and wet conditions on sediment yield in different watersheds throughout the world.

#### 4. Conclusion

Average rainfall and sediment yield were found as 403.9 mm and 6920.7 ton for the meteorological drought years and 536.7 mm and 18068.2 ton for the meteorological wet years, respectively. These values were measured as 30.7 mm and 7417.8 ton for the hydrological drought years and 87.3 mm and 21489.2 ton for the hydrological wet years. The sediment yields were found similar within the meteorological and hydrological wet conditions and at the same time within the meteorological and hydrological drought conditions. Average sediment yield was found statistically significant at meteorological and hydrological drought and wet years. In Uğrak watershed, cultivated lands cover larger areas than grassland and shrub areas therefore much more soil erosion occurred in wet years in the watershed. In the study, negative correlation between drought and sediment yield was also found.

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