ANALYSIS OF RAINFALL EROSIVITY
AND CLIMATIC FACTOR OF WIND EROSION

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ABSTRACT

In this paper, spatial and temporal variation of rainfall erosivity and climatic factor of wind erosion are investigated. Climatological data of monthly mean and annual total precipitation, mean wind speed, air temperature and evaporation observed at the different geographical regions in Turkey between 1929-1990 are analysed. Higher values of Fournier Index are observed in North-eastern Black Sea, Southern Aegean Sea and Mediterranean Sea Regions. The lower ones are recorded in Eastern and Central Anatolia. Climatic factor of wind erosion shows higher values in Southern and Eastern Anatolia, Aegean Sea and Mediterranean Sea regions. Climatic factor of wind erosion decreases in Black Sea Region and Trakian Part of Turkey. The results of this paper show that Aegean and Mediterranean Sea Regions are under the combined effects of wind and water erosion.

Key Words: Water and Wind Erosion, Runoff Factor, Climate Factor, Fournier Index.

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1. INTRODUCTION

Water causes soil erosion mainly by (i) the impact of raindrops on the soil surface and (ii) its flow between rills and in channels down slope. It also causes landslides on steep slopes when soil overlying material of low permeability becomes saturated with water of rain or overland flow. A landslide can cause devastation when the whole soil, together with trees and buildings, slides downhill. The erosivity effect of raindrops will be understood if we consider the energy of a rainstorm, Wild, (1993), Gabriels (1993), Oduro-Afriye (1989), Barry and Chorley (1992) and Ploey (1983).

Wind erosion climatic erosivity is a measure of the climatic tendency to produce conditions conducive to wind erosion. Strong winds erode and dryness increases the susceptibility of the surface to erosion, Skidmore, (1995).

Wind causes the erosion of dry bare soil. The two factors that determine its extent are wind speed and the size of the soil particles and aggregates. Experiments in wind tunnels have shown that the carrying capacity of wind for soil particles increases greatly with wind speed and decreases with particle and aggregate size. Soil erosion effects on soil properties in a highland near central Kenya was investigated by Gachene et al. (1997).

The version of the wind erosion model is presented with two major modifications by Skidmore (1995). A wind simulator to furnish wind direction and sub hourly wind speed to users of wind speed information, particularly for wind erosion modelling was developed by Skidmore and Tatarko (1990).

2. METHODOLOGY

2.1. Rainfall Erositivity Factor and Water Erosion

The amount of erosion at any site depends on the erosivity of the rainfall, the erodibility of the soil, the characteristics of the land, ad its use and management. The following regression relation to estimate soil loss is known as the Universal Soil Loss Equation (USLE), Wild (1993) and Agassi (1996):

\[ A = R \cdot K \cdot L \cdot S \cdot C \cdot P \]  

where

\[ A \]: Computed average spatial and temporal soil loss per unit of area
\[ R \]: Rainfall and runoff erosivity factor
\[ K \]: Soil-erodibility factor
\[ L \]: Slope - length factor
\[ S \]: Slope - steepness factor
\[ C \]: Cover and management factor
\[ P \]: Supporting practice factor

Rainfall and runoff erosivity factor are obtained from:

\[ R = A / (K \cdot L \cdot S \cdot C \cdot P) \]  

where A, K, L, S, C and P are based on field measurements. Some authors have attempted to calculate R by correlating annual precipitation and monthly precipitation with known R - factors. The following regression relations are used for U.S. CITY DATABASE information, Agassi (1996):

\[ R = 0.0048 \cdot P^{1.61} \]  

where
and

\[ R_1 = 0.074 \ C_p^{1.85} \]  \hspace{1cm} (4)

\[
C_2 = \sum_{i=1}^{12} \frac{P_i^2}{P} \]  \hspace{1cm} (5)

where

- \( R \): Rainfall and runoff factor (N.h/100Yr.)
- \( P \): Annual precipitation (mm)
- \( C_p \): Fournier Index (mm)
- \( P_i \): Monthly precipitation (mm).

Relations had high coefficients of determination \((r^2=0.81)\). In this paper equations (3), (4) have been considered to determine runoff erodivity factor.

### 2.2 Climatic Factor of Wind Erosion

Experiments in wind tunnels have shown:

\[ C \alpha V^3 \ d^{12} \]  \hspace{1cm} (6)

where

- \( C \): Quantity of soil removed
- \( V \): Wind speed
- \( d \): Particle diameter.

Wind speed is generally measured 2m above mean ground level. Near the soil surface the speed is less because of frictional resistance; also the flow of air is broken up into eddies by stones and aggregates, Wild (1993).

The climatic factor of wind erosion \((C_w)\) was expressed as,

\[ C_w = 386 \ u_{av}^3 / (PE)^2 \]  \hspace{1cm} (7)

where

- \( u_{av} \): Mean wind speed,
- \( PE \): Thornthwaite’s Index, Skidmore (1995).

The term 386 indexes the factors to the conditions at Garden City, Kansas. Thorthwaite’s Index to evaluate precipitation effectiveness expressed as below:

\[ PE = 3.16 \sum_{i=1}^{12} \ [P_i / (1.8T_i + 22)]^{0.69} \]  \hspace{1cm} (8)

where,

- \( P_i \): Mean monthly precipitation (mm),
- \( T_i \): Mean monthly air temperature (°C).
Equations (7) and (8) are used to determine wind erosion climatic factors for many locations in the U.S. Skidmore (1995). In the present paper these equations have been taken into account.

3. ANALYSIS

3.1 Analysis of Rainfall Erosivity Factor and Water Erosion

Table 1 shows station number and height above near sea level at different geographical regions in Turkey. Spatial variation of long-term (1929 - 1990) mean annual total precipitation values are given in Fig. 1. Station number corresponds to the climatological stations in Table 1. Maximum annual precipitation values are observed in Rize (21), Mugla (20) and Antalya (3) as 2146.4mm, 1160.7mm and 1052.38mm respectively. The average value and standard deviation of annual precipitation in Turkey are 611.3mm and 378.8mm. Minimum values are observed in Konya (320.6mm), Kayseri (363.8mm) and Erzincan (369.7mm).

Variation of Fourniex Index Values in Turkey is presented in Fig. 2. Index values change between 33.2mm and 224.0mm. The maximum values are observed in Antalya (3), Mugla (20) and Izmir (15) as 236.4mm, 224.0mm and 137.5mm, respectively. The average value and standard deviation of Fournier Indexes in Turkey are 87.44mm and 53.2mm. The minimum Fournier Index values are observed in Erzincan (33.2mm), Konya (44.21mm) and Kayseri (48.6mm).

Table 2 shows the class numbers and intervals of Fournier Index. Class numbers 1 and 5 correspond to the lowest and highest rainfall erosivity factor values, respectively. Spatial Variation of Fournier Index class values based on observation between 1929 and 1990 and Eq. (5) are presented in Figure 3. The highest values are observed in North-eastern Black Sea, Southern Aegean Sea and Mediterranean Sea Regions. The lowest values are recorded in the terrestrial part of Turkey, Eastern and Central Anatolia.

Figure 4(a-d) shows temporal variation of Fournier Index values in Adana (1951-1990), Erzincan (1951-1985), Konya and Malatya (1951-1990). Index values show the increasing trend at this period in these stations. The decreasing trend of Fournier Index values are observed in other stations. Figure 5 (a-c) shows the trend of Fournier Index in some stations (Bursa, Canakkale and Mugla) based on the observations between 1951 and 1990.

Comparison of rainfall and runoff factors computed by using Eqs. (3) and (4) are presented in Fig. 6. Maximum values are observed in Antalya (2046.1Nh/100Yr), Mugla (1795.1Nh/100Yr) and Izmir (716.4Nh/100Yr). Average values of these factors are R=365.2Nh/100Yr and R1 = 140.1Nh/100Yr in Turkey. For the lower annual precipitation values, differences between these two factors are small. Bias values are 93%, 76% and 74% in Antalya, Mugla and Izmir respectively. The lower biases of them are determined in Rize (5%), Erzincan (7%) and Bolu (12%).

3.2 Analysis of Climate Factor and Wind Erosion

Fig. 7 shows Thornwaite's Index and annual average value of wind speed values at different stations in Turkey. The maximum TI values are observed in Rize (21) and Antalya (3). The minimum ones are in Adana (0) and Malatya (19). Maximum wind speed value is recorded in Canakkale (4.7m/s).

Table 3 shows the class values of climatic factor. Class numbers 1 and 5 correspond to the lower and higher climatic factor of wind erosion, respectively.

The spatial variation of climatic factor of wind erosion ($C_w$) is presented in Fig. 8. The higher values are observed in Siirt (196736), Diyarbakir (21162.4), Elazig (3178.6), Gaziantep, (3149.9), Antalya (954.5), Kirsehir (316.8), Izmir (275.8), Malatya (264.6), Mugla (191.9) and Canakkale (145.7). The minimum values are observed in Trabzon (0.38), Edirne (0.88) and Bolu (1.0). The average value and standard deviation of climatic factor are 94.63 and 113.62 in Turkey, respectively. Climatic factors of wind erosion show higher values in Southern, Eastern Anatolia,
Aegean Sea and Mediterranean Sea Regions than other parts of Turkey. The lower ones are determined in the Black Sea Region and Trakian part of Turkey.

Maximum values of climatic factor are observed in Istanbul in August, July and June; in Izmir in July, August and June; in Kayseri, in August, July and June; in Konya, Malatya and Mugla, in July, August and September, and in Rize in May, June and July. Maximum climatic factor values of wind erosion are observed in November, October and September and minimum climatic factor values are recorded between December and February at other stations. But in Samsun, minimum values are observed in October and November.

4. RESULTS AND CONCLUSION

Spatial and temporal variations of Climatic factor of wind erosion and rainfall erosivity have been analysed in this paper. As a conclusion:

After the comparison of Fournier Index variation, the higher rainfall erosion is observed in North-eastern Black Sea, Southern Aegean Sea and Mediterranean Sea Regions. The lower values of Fournier Index are recorded in the terrestrial part of Turkey, especially in Eastern and Central Anatolia. Climatic factor of wind erosion shows higher values in Southern and Eastern Anatolia, Aegean Sea and Mediterranean Sea Regions. Lower climatic factor values of wind erosion are observed in Eastern Black Sea Region and the Trakian part of Turkey. Stronger combined effects of water and wind erosion are observed in Aegean and Mediterranean Sea Regions in Turkey. Their effects play an important role on agricultural and archaeological fields in these regions. This paper is related to the general classification of degrees of water erosion, rainfall and wind erosivity factors. For more detailed analysis small scale variations and local effects have to be taken into account. A forthcoming study will be related to the analysis of local effects on rainfall and wind erosion factors.

Acknowledgements

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REFERENCES


TABLE CAPTIONS

Table 1- Station Number and Height of Stations at Different Geographical Regions in Turkey.

Table 2- Class Values of Fournier Index

Table 3- Class Values of Climatic Factor
### TABLE 1

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### TABLE 2

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FIGURE CAPTIONS

Fig. 1- Variation of Annual Total Precipitation (P, mm) in Turkey, (1929-1990).

Fig. 2- Variation of Fournier Index Values (Cp, mm) in Turkey, (1929-1990).

Fig. 3- Spatial Variation of Fournier Indexes (Cp, mm) in Turkey, (1929-1990).

Fig. 4- Increasing trend of Fournier Index Values (Cp, mm) in Adana (a), Erzincan (b), Konya (c) and Malatya (d), (1951-1990).

Fig. 5- Decreasing trend of Fournier Index Values (mm) in Bursa (a), Canakkale (b) and Mugla (c), (1951-1990).

Fig. 6- Variation of Rainfall and Runoff Factors (R, R1, Nh/100Yr) at Different Stations, (1929-1990).

Fig. 7- Variation of Annual Thornthwaite Index (TI) and Mean Wind Speed (V, m/s) at Different Stations in Turkey, (1929-1990).

Fig. 8- Variation of Climatic Factor of Wind Erosion (Cw) at Different Stations in Turkey, (1929-1990).
Fig. 3

Fig. 4 (a)
Fig. 4 (b)

Fig. 4 (c)
Fig. 6

Fig. 7