Tarım Bilimleri Araştırma Dergisi 7 (2): 33-36, 2014
ISSN: 1308-3945, E-ISSN: 1308-027X, www.nobel.gen.tr

The Effects of Forestation on RUSLE-K Factor in Lowland Ecosystem of Semi Arid Areas in Turkey

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Received: August 05, 2014
Accepted: September 12, 2014

Abstract

This study was conducted to determine variations in Soil Erosion Factor (K) of Revised Universal Soil Loss Equaiton (RUSLE) and some significant soil properties related to RUSLE-K factor due to forestation on sandy soils of the Igdır Urban Woodland in the north-eastern part of Turkey. 60 surface soil samples were collected from 0-20 cm depth in different 5 locations (9-year, 7-year, 3-year, and 1-year forested and bare land). Soil susceptibility to erosion was estimated using the measured soil properties and soil erodibility nomograph. Soil organic matter (SOM), texture, pH, and aggregate stability (AS) were the soil properties that were analyzed to evaluate such effects. Variations in RUSLE-K, SOM, and WSA were statistically significant at the level of $p<0.05$. These results strongly suggested that forestation in different stages caused melioration in RUSLE-K and soil properties.

Key words: Forestation, RUSLE-K, soil erodibility, soil aggregation.

Türkiye'deki Yarı Kurak Ova Ekosistemlerinde Ağaçlandırmanın, Yenilenmiş Üniversal Toprak Kayıpları Eşitliğindeki Toprak Erozyon Faktörü (K) Üzerine Etkisi

Özet

Bu çalışma Türkiye'nin kuzeydoğusunda yer alan Iğdır ili kent ormanı kumlu topraklarında, ağaçlandırmanın, yenilenmiş üniversal toprak kayıpları eşitliğindeki (RUSLE) toprak erozyon faktörü (K) ve bu faktörle ilgili bazı önemli toprak özellikleri üzerindeki etkilerini belirlemek için yapılmıştır. Beş farklı ağaçlandırma bölgesinde (9 yıllık, 7 yıllık, 3 yıllık, 1 yıllık ağaçlık ve çıplak arazi), 0-20 cm derinlikten 60 adet yüzey toprak örneği alınmıştır. Ölçülmüş toprak özellikleri ve toprak aşınım abağı kullanılarak toprak örneklerinin erozyona karşı duyarlılığı belirlenmiştir. Toprak özelliklerinden toprak organik maddesi, toprak tekstürü, pH ve agregat stabilitesinin etkilerinin değerlendirilmesi için analiz edilmiştir. Toprak erozyon faktörü (K), organik madde ve agregat stabilitesindeki farklılıklar $p<0.05$ seviyesinde istatistiksel olarak önemli bulunmuştur. Bu sonuçlar, ağaçlandırmanın, toprak erozyon faktörü (K) ve toprak özellikleri üzerinde iyileştirici etkilerini desteklemiştir.

Anahtar kelimeler: Ağaçlandırma, toprak erozyon faktörü, toprak aşınımı, toprak agregatlaşması.

INTRODUCTION

Deforestation and accordingly emerging erosion are serious hazards in arid and semi-arid regions of developing countries. Inappropriate land use and climate events (high winds, heavy rainfall) increase the soil erosion. Lands of Igdır showing features of semi-arid climate are under the influence of both wind and water erosion due to irregular and insufficient rainfall and excess evaporation.

Being a resistance estimation of a soil material against the impact of raindrops on the soil surface and the tangential action of concentrated flow, RUSLE-K factor measures the soil susceptibility to erosion [1]. By using the soil erodibility nomograph Evrendilek et al. [2] measured RUSLE-K [3] to assess the effects of changes in three adjacent ecosystems (forest, grassland, and cropland) in Mediterranean plateau having a high altitude in Turkey. According to the results obtained, the soil erodibility increased as a result of transformation of grassland into the cropland in the southern Taurus Mountains located in the Mediterranean region. USLE-K factor was measured by Çelik [4] for cultivated land and pasture, in 0-10 and 10-20 cm soil depths. USLE-K factor was determined to be nearly two times greater in the cultivated land compared to the pasture, which signified the vulnerability of the cultivated land to water erosion. Consequently, the results revealed that soil physical properties deteriorated due to the cultivation of the pastures and soils became more susceptible to the erosion. It was emphasized that land degradation needs to be strictly prevented in the pastures with insufficient soil depth in the southern Mediterranean highlands.

Soils of arid and semiarid areas become very susceptible to water erosion especially because of the scarce vegetation cover, low organic matter content, and the small resistance to the erosion forces [5]. The magnitude of water erosion is also affected by their texture, water content, evaporation, percolation, and lixiviation. These soil characteristics are not proper in terms of the resistance of the soil to water erosion [6]. In terms of soil orders, Aridosol, Alfisols, Entisols, Molisols, and Vertisols are among soils belonging to typical arid and semi-arid zones in the world [7]. Being a natural geological phenomenon the erosion is caused by removal of topsoil by natural agencies such as wind, water and some human interventions significantly increase erosion rates. The erosion, which is both a major agricultural problem but also one of the major global environmental issues, has some triggering factors such as slope steepness, climate (e.g. long dry periods followed by heavy rainfall), inappropriate land use, land cover patterns (e.g. sparse vegetation), and ecological disasters (e.g. forest fires) [8]. Furthermore, some basic features of the soil such as a thin layer of topsoil, silty texture and low organic matter content could cause the soil to be more susceptible to erosion [9].

Başaran et al. [1] utilized the land use and soil cover changes to determine changes in some of important soil properties. Forested soils were investigated in terms of soil organic carbon, total nitrogen content, available phosphorous and potassium, calcium carbonate content, thickness of A horizons and some important soil properties and compared with the adjacent deforested and cultivated soils [10]. Changes in land use causes conversion in structure of highlands and accordingly creates a widespread danger for health of ecosystems and high risks for soil quality and erosion. Soil organic carbon can be significantly affected by changes in land use due to humidification, decomposition and mineralization of SOM. Land degradation and loss of soil organic matter are closely associated with the deterioration of significant soil physical properties such as poresize distribution, bulk density, aggregation and aggregate stability [11, 12, 13, 4]. In the study conducted by Oguz and Acar [14], they determined the effect of different land use on soil properties in the province of Tokat. Topsoil and subsoil samples were taken from four different land use types (forest, grassland, orchard, and farmland). There were significant statistical differences between different types of land use and topsoil organic matter, pH, total nitrogen, P and K contents. It is known that transformation of natural ecosystem to agriculture and the increase in intensity of tillage decrease SOM levels because of reduced inputs of organic matter, reduced physical protection of soil organic carbon (SOC) caused by tillage [15]. Guo and Gifford [16] stated that soils lost 42 and 59% of their SOC stock as a result of conversion from forest to crop and from grassland to crop, respectively. Transition from forests to agricultural lands causes important decreases in SOM of the topsoil due to the land use [17].

This study was conducted to assess the effects of forestation in different stages on soil aggregation and resistance to erosion in a lowland ecosystem of Igdır, having a semi-arid climate, in Turkey [18].

MATERIAL AND METHODS

The study site was located in the Igdır Urban Woodland in the north-eastern part of Turkey. Selected site for this study contained five woodland stages in 9-year, 7-year, 3-year, and 1-year wooded and bare land. Because of being lowland, alluvial soils took part in the study area. Generally, soil texture is sandy (S) in all forested and bare lands.

Long term annual average temperature was 12.1°C, annual total precipitation was 256.0 mm, annual total evaporation was 1116.3 mm, annual average solar radiation was 319.7 cal cm^{-2}, and annual average relative humidity was 55.3 (%) for the study area [18].

With regular intervals, soil samples were taken from 0-20 cm depth from 60 locations of disturbed soil sampling, and were analyzed in terms of clay, silt, and sand contents by using the hydrometer method [19], in terms of SOM content by using the method of Walkley and Black [20], and in terms of pH by glass electrode in a 1:2.5 soil/water suspension [21]. Their WSA was determined according to Kemper and Rosenau [22]. RUSLE-K factors were calculated by the soil erodibility nomograph [3].

RESULTS AND DISCUSSION

Table 1 illustrates analysis of variance in order to compare the effects of different wooded stages on RUSLE-K, WSA, SOM, pH, and texture of surface soils in 0-20 cm depth.

RUSLE-K factors, as an indicator for (1) the susceptibility of soil or surface material to erosion, (2) the transportability of the sediment, and (3) the amount and rate of runoff given for a particular rainfall input, as measured under standard conditions [23], had a statistically significant difference ($p<0.05$) in terms of forestation. 9-year wooded land had also a statistically significant difference compared to others according to Tukey ($p<0.05$). There were slight and regular decreases in the values of RUSLE-K factors from bare land to 9-year wooded. It means that the more forestation is the less erosion is.

Table 1. Analysis of variance for soil properties as affected by different wooded stages.

S. P.	Bare land	Woodland			
		1-year	3-year	7-year	9-year
K	0.42^{A}*	0.41^{A}*	0.39^{A}*	0.37^{A}*	0.30^{B}*
AS %	27.35^{B}*	26.52^{C}*	27.47^{B}*	29.97^{B}*	43.49^{A}*
SOM	1.15^{D}*	1.55^{C}*	1.85^{B}*	2.44^{A}*	2.61^{A}*
pH	7.55	7.54	7.44	7.55	7.44
Si %	17.50	18.85	20.22	19.27	19.35
C %	20.67	21.30	21.92	20.03	20.65
S %	61.83	59.85	57.87	60.70	60.00

S. P.: Soil properties; K: soil erodibility factor of RUSLE.
AS: Aggregate stability; SOM: soil organic matter;
pH: soil reaction; Si: silt; C: clay; S: sand;
Capital letters indicate statistically significant differences (p<0.05) among different wooded stages according to Tukey test.
Symbol (*) indicates statistically significant differences (p<0.05) among soil properties affected by the different wooded stages.

Aggregate Stability (AS%) refers to resistance of soil aggregates against disintegration as a result of wetting and rain drop impact effect. It is also an indicator for resistance of the soil against soil compaction. The values of aggregate stability (AS%) were statistically affected by forestation ($p<0.05$) in the study area. According to Tukey test, 1-year and 9-year wooded lands were statistically different from others. The others were statistically similar. Forestation in especially 9-year wooded land improved aggregate stability (59%).

Since Soil organic matter (SOM) plays a role in several key functions, it is a key indicator of soil health. They are biological, chemical, and physical functions. These functions have frequently strong interactions. For instance, the heat energy resulting from chemical interactions increases microbial activities, accelerates organic matter decomposition and improves capacity of nutritional elements of the soil and its structural stability. Forestation from bare land to 9-year wooded land had a statistically significant difference ($p<0.05$) in terms of the SOM in the site. There was no statistically significant difference between 9-year and 7-year wooded land but was a statistically significant difference among bare land, 1-year, and 3-year wooded land according to Tukey test ($p<0.05$). Increments from bare land to 9-year wooded land were by 34%, 19%, 24% and 7%, respectively.

In terms of agriculture, soil and creatures, pH is a very important chemical indicator due to its effect on plant growth, nutrient availability, elemental toxicity, and microbial activity. On the other hand, the soil pH indirectly affects the plant growth. Availability of various mineral nutrients depends on the pH of soil. At certain pH levels, certain mineral nutrients are available for the plants. Even though other elements are present in the soil, they are unavailable to the plants since their pH values are not appropriate. There were no statistically significant differences in pH values ($p<0.05$) and among wooded stages. All pH values were in the alkaline side of the pH scale but were close to the neutral side of the pH scale.

The texture have an effect on numerous soil properties, such as drainage, water holding capacity, aeration, susceptibility to erosion, organic matter content, cation exchange capacity (CEC), pH buffering capacity, and soil tilth. Soils differ in their susceptibility to erosion (erodibility) based on texture; a soil having a high percentage of silt and clay particles has a greater erodibility compared to a sandy soil under the same conditions. Differences in soil texture also affect organic matter levels; and organic matter breaks down faster in sandy soils compared to fine-textured soils, under similar environmental conditions, tillage and fertility management, due to a higher amount of oxygen available for decomposition in the light-textured sandy soils. Statistics of silt, clay, and sand demonstrated that these did not change with forestation ($p<0.05$). General texture class in the study area was sandy. The effects of forestation on soil texture were not observed except for slightly increase of silt contents from bare land to 9-year wooded land.

CONCLUSIONS

Forestation (bare land, 1-year, 3-year, 7-year, and 9-year wooded) in Igdır Urban Woodland in the north-eastern part of Turkey was examined to assess the effects of wooded stages on soil aggregation and resistance to water erosion. Soil samples collected from 0-20 cm depths with regular intervals in an area of 500 m x 2000 m were characterized for SOM, pH, texture, AS, to algebraically estimate RUSLE-K together with field assessment of soil structure. Analysis of variance was performed to evaluate the dynamic relationships between SOM, pH, texture, and AS to algebraically estimate RUSLE-K as affected by different wooded stages.

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