The International Journal of Energy & Engineering Sciences, 2020, 5 (1) 12-20
ISSN: 2602-294X - Gaziantep University

THE ERODIBILITY FACTOR IN AGRICULTURAL LANDS OF GAZIANTEP, TURKEY

Erdihan TUNÇ
University of Gaziantep, Faculty of Arts & Science, Department of Biology, 27310 Şehitkamil, Gaziantep, Turkey
tunc@gantep.edu.tr

ABSTRACT

Soil erosion is the most important land degradation worldwide. Turkish soils are highly threatened by erosion mainly due to natural physical-geographic conditions as well as historic and current land-use. A number of soil erosion studies have been performed for different parts of Turkey; however, no erodibility potential-related data is available for Gaziantep province. In this study we evaluate the susceptibility of agricultural land in Gaziantep province to erosion (erodibility potential) by the use of the erodibility factor K on the basis of the soil texture, soil organic matter (SOM) content, soil aggregation and water permeability. Moreover, the nutrient supply of soils was investigated in order to further elucidate the impact of soil erosion on soil fertility. The study revealed that all investigated soils had to be categorized as threatened by erosion due to a high to extremely high erodibility potential, with K-factors ranging between 0.33 and 0.79. Further K-factor was positively correlation to SOM as well as aggregate stability (ΔGMD) mainly due to grain-size compositions. According to these results, there is a generally high risk of erosion for the investigated soils and future erosion events might also be followed by a measurable loss of nutrients and subsequently loss of soil fertility. As a major outcome of the present survey, a regional soil protection concept should be developed and implemented for Gaziantep region, wherein the study results provide a basis for information sessions with regard to erosion.

Keywords: aggregate stability, soil erodibility, soil fertility, soil nutrients

1. INTRODUCTION

Soil erosion is defined as the detachment, entrainment, transport, and deposition of soil particles [1]. It is one of the main problems of modern human environmental interactions [2]. In light of global food security soil erosion is a principal problem because of its potential adverse impact on soil productivity and sustainability. Soil erosion may also threaten further soil functions and ecosystem services impacting many aspects of human life and the environment including air and water quality [3,4]. Soil erosion involves the detachment of soil particle and their subsequent transport by water or wind [5,6]. For example soil detachment by water occurs when raindrop impact energy and/or shear stress of overflow exceed the cohesive strength of soil particles and the subsequent sediment transport occurs by the raindrop splash and surface water flow impact [7].

Soil erodibility, is an intrinsic soil property, which reflects the sensitivity of the soil to erosion under certain erosivity forces caused by environmental conditions affecting soil's structural stability such as landscape features, land use system and climate includes rainfall and runoff [8-11]. Soil erosion is strongly related to agriculture and associated historical and recent land-use changes [1, 12] such as cropping systems that are characterized by the lack of soil surface coverage, tillage erosion, soil erosion due to land leveling and crop harvesting [1,13]. Thus resulting, loss of soil fertility from the loss of nutrients and soil organic carbon (SOC) or humus.

Soil erodibility factor (K-factor) is widely considered as a significant parameter in estimating soils’ susceptibility to splash detachment and transport by surface flow [14,15]. Since soil susceptibility to erosion is affected by a large number of physical, chemical and mechanical soil properties as well as hydrological processes, quantifying K-factor is complicated. However, over the period of time a more simplified relationships have been proposed [16]. The K-factor of RUSLE [17] has been widely used for estimation of soils’ susceptibility to splash detachment and transport by surface flow.

According to [18], more than 50 % of Turkish soils are threatened by erosion, whereby the amount of soil material eroded solely by water was estimated to be 380 to 500 million Mg per year The particular reasons for soil erosion in Turkey are i) the natural physical-geographic conditions, such as parent rocks, substrate, relief, and climatic conditions, as well as ii) historic and current land-use (e.g. deforestation, overgrazing, intensity in general) [19-21]. Consequently, a wealth of soil erosion studies have been performed for different parts of Turkey within the last years [22-26]. However, as far as we know, no erodibility potential-related data is available for Gaziantep province. Therefore, the aim of the present study was to evaluate the susceptibility of agricultural land in Gaziantep province to erosion (erodibility potential) by the use of the erodibility factor K [27], with soil texture, soil organic matter content, aggregate stability (class) and permeability (class) as input factors. Furthermore, the nutrient supply of soils as well as further soil chemical parameters were investigated in order to elucidate the impact of soil erosion on soil fertility and to assess the present conditions of soils with regard to their nutrient supply.

2. MATERIALS & METHODS

2.1 General characteristics of the study area

Soil erosion investigations were conducted for five regions within Gaziantep province, which is located at the border of the Mediterranean and south-eastern Anatolia and borders northern Syria in the south.

In general, the study area is marked by hilly surfaces; limestone and gypsum are common substrates for soil genesis [28]. The climatic conditions of south-eastern Anatolia are distinctly continental with dry and hot summers and cold winter times. Chromic Cambisols developed on more than 55 % of the area, followed by colluvial soils (approx. 23 %). Further soil types (< 10 % of area) are Cambisols, soils from basaltic parent rock, Regosol, Terra rossa, and Terra fusca [28]. The natural vegetation mainly consists of grasslands with dwarf shrubs and, to a smaller extent, also steppe, garrigue, forest and macchia. Several kinds of cash crops are cultivated, such as pistachio, olives, almonds, oak coppice, barley, wheat, chickpeas, lentils and on occasion also wine.

2.2 Analysis of soil physical and chemical parameters

Soil samples were taken with a soil core sampler from 0-25 cm depth at the beginning of the vegetation period in the years 2008 to 2010. The samples were sieved (2 mm mesh size) and air dried for soil chemical analysis. The pH was determined potentiometrically within a CaCl2-solution (0.01 M), using a Hanna pH-electrode (HI 83140 model) [29], whereas determination of electrical conductivity (EC) followed [30]. The CaCO3 content was measured by means of the Scheibler-method [31] by the use of Eijkelkamp M1.08.53.D model calcimeter. Soil organic C content (Corg, syn. SOM) was measured by dry combustion at 550°C with a Leco-RC 412 analyzer [32]. Fe-, Zn-,Mn-, and Cu-contents were determined according to [33] by use of an AAS device (Perkin Elmer AA Accessory Cooling System), K, Ca and Mg via AAS device (Perkin Elmer) after [34].

Grain size analysis followed [35] by means of Retsch Model AS 200. Aggregate stability was determined by wet sieving [36]. Here, air dried soil samples were first separated into aggregate fractions of 8-5, 5-3, and 3-2 mm by sieving. The weight was determined for each fraction before aggregates were admixed again, rewetted with distilled water and placed together on the top of a sieve cascade (consisting of sieves with mesh sizes of 5, 3, 2, and 1 mm). The cascade was then moved up and down within water for 5 minutes (35 cycles min-1). Aggregate stability was calculated subsequently by determining the difference between the mean aggregate size (weighted mean aggregate diameter = ΔGMD) before and after wet sieving. Soil permeability was determined according to [37] Aggregate stability classes as well as soil permeability classes were taken from AG Boden (2005) and the K-factor was calculated acc. to [27]:

$$K = 2.77 \times 10\text{-}6 \times M1.14 \times (12-OM) + 0.043 \times (A-2) + 0.033 \times (4-D),$$

where K represents the K-factor (erodibility potential), M = (% silt + % fine sand) × (% silt + % sand (excluding fine sand)), OM = % organic matter (syn.: Corg/SOM), A = aggregate class, and D = permeability class.

2.3 Statistical analyses

Correlations between variables were tested using the correlation coefficient r according to Pearson. Kruskal-Wallis H tests ($p < 0.05$) were performed to test for significant differences between the different types of land-uses and regions, as not the complete data-set fulfilled the statistical requirement of normal distribution. Results were presented as arithmetic means (AM) ± standard deviation (SD). All tests were performed using IBM SPSS Statistics 21.0 software package.

3. RESULTS & DISCUSSION

Table 1 provides the physical and chemical properties of the soils. The pH-values of investigated soils was alkaline, which is in accordance with the generally high contents of alkaline cations where it showed a significant positive correlation for Ca, Mg and CaCO3 (Table 2). Both K-factor and ΔGMD were negatively correlated to Cu and Mn, indicating that these cations were important for soil aggregation of investigated soils, however, no significant correlations could be described for CaCO3 [39].

According to [33] the sites can be identified as having sufficient Cu (> 0.2 ppm) and Mn (> 1 ppm) supply, whereas the Fe supply was insufficient (< 2.5 ppm). The Zn content was considered too low at 66 % of the sites. In general, the measured contents revealed to be very high (> 2.56 ppm) for K, Ca and Mg [40]. High potassium levels may degrade the structural stability of the soil and consequently lead to silting-up of soils, which in turn promotes erosion [41]. Based solely on soil texture, 22% of the total investigated soils was characterized by high susceptibility to water erosion while the remaining, 66% and 13% showed medium and minor susceptibility to water erosion respectively [38] (Supplementary table 1). Susceptibility to water erosion increases with increasing silt contents [35].

Considering SOM content, aggregate stability (class) and permeability (class), the calculation of site-specific K-factors revealed that all investigated soils had to be categorized as threatened by erosion due to a high to extremely high erodibility potential, with K-factors ranging between 0.33 and 0.79 [38]. As the K-factor is a function of the before mentioned variables and the particle size fractions of silt, sand and fine sand, the K-factor was significantly correlated to ΔGMD ($r = 0.85$), percolation rate ($r = -0.60$), and the clay content ($r = -0.68$), respectively. The K-factor is moreover influenced by SOM as this parameter is considered to have an influence on the forming of structure and stabilization of aggregates and thus decreases the detachment and transport of soil substance [43,44]. Consequently, correlation coefficients were $r = 0.31$ for K-factor and SOM and $r = 0.43$ for ΔGMD and SOM (both significant), respectively, and it is likely that the generally low SOM contents of the study sites might be responsible also for the increase in erodibility potential of the soils that categorized before as a minor prone to erosion, on the basis of their particle size fractions. For example, soils (at site 30) that were classified as medium susceptible to water erosion showed considerably higher erodibility potential 50 this increase was mainly related to the SOM content, which was extremely low (0.42 g kg-1 Corg) compared to the other medium susceptible soils (2.3 and 2.5 g kg-1 Corg, respectively).

Besides the abiotic factors, the naturally given soil texture, agricultural land-use generally exerts strong influence on both SOM and permeability. The SOM content e.g. depends on the respective cropping system, in particular the biomass input by above- and belowground harvest residues, intertillage cropping, and the intensity of soil tillage. In particular the frequency and depth of soil tillage, e.g. by ploughing, promotes mineralization rates by increased soil aeration as well as shifting of organic residues to the soil surface. On the other hand, field traffic may also cause severe soil compaction leading to a decrease in both permeability and aeration [44].

However, within the present study the erodibility potential did not differ significantly between the different types of land-uses (H-test, $p < 0.05$) and thus, no detailed conclusions could be drawn for the respective investigated land-uses, which were pistachio & olive, pistachio, wheat, olive groves, and fallow. As even the five different regions did not differ from each other (H-test, $p < 0.05$), it is evident that, within the present study, soil texture was the crucial parameter, determining the basic potential for erodibility.

4. CONCLUSIONS

The study revealed that soils of Gaziantep province were highly prone to erosion mainly due to their grain-size compositions. Besides the alkaline soil conditions at most of the investigated sites, the general low SOM contents further increased the erodibility potential. As a consequence, agricultural land is severely threatened to lose soil fertility by erosion of nutrients, even though nutrient supply was presently sufficient for most of the investigated nutrients (with exception of K, Ca and Mg). Our findings, therefore, can be used as a basis to develop and implement a regional soil protection concept for Gaziantep region.

Table 1. Soil physical and chemical properties

	Soil chemical properties											Soil physical properties		
	pH	EC mS cm^{-2}	Ca mg kg^{-1}	K mg kg^{-1}	Mg mg kg^{-1}	Zn mg kg^{-1}	Mn mg kg^{-1}	Fe mg kg^{-1}	Cu mg kg^{-1}	$CaCO_3$ %	SOM g kg^{-1}	ΔGMD	percolation ml sec^{-1}	K-factor
AM	7.6	0.07	4221	55	320	0.85	4.50	1.33	2.51	16	2.3	20	158	0.51
(± SD)	0.1	0.02	1184	15	161	0.68	1.98	0.40	0.89	9	2.5	12	93	0.14

Table 2.1 Correlation between soil physical and chemical properties of the study area

	pH	EC	Ca	K	Mg	Zn	Mn	Fe	Cu	$CaCO_3$	SOM	Clay	ΔGMD	PERC	K-factor
pH	1														
EC	-.070	1													
Ca	.507**	-.361*	1												
K	-.772**	.248	-.643**	1											
Mg	.403**	-.173	.099	-.256	1										
Zn	-.075	.186	-.713**	.070	.130	1									

*Significant (two-tailed) at $p< 0.05$ by least significant difference (LSD).** Significant (two-tailed) at $p< 0.01$ by LSD; PERC: Percolation; ΔGMD: aggregate stability; SOM: Soil organic matter; EC: electron conductivity.

ACKNOWLEDGEMENTS

We would like to thank the Gaziantep University for funding the project (BAPB FEF0808) and the department of forestry for providing some data.

REFERENCES

[1] Boardman, J., Poesen, J. (2006): Soil erosion in Europe: Major Processes, Causes and Consequences, in: Boardman, J., Poesen, J. (eds.), Soil erosion in Europe. John Wiley & Sons, Chichester, West Sussex, p. 479-489; 479, 480, 481, 484, 485.

[2] Pimentel, D., Harvey, C., Resosudarmo, P., Sinclair, K., Kurz, D., McNair, M., ... & Blair, R. (1995). Environmental and economic costs of soil erosion and conservation benefits. Science, 267(5201), 1117-1123.

[3] Zhu, B., Li, Z., Li, P., Liu, G., & Xue, S. (2010). Soil erodibility, microbial biomass, and physical–chemical property changes during long-term natural vegetation restoration: a case study in the Loess Plateau, China. Ecological Research, 25(3), 531-541.

[4] Millennium Ecosystem Assessment (2005): Ecosystems and Human Well-being: Synthesis. Island Press, Washington, DC, p. V.

[5] Lal, R. (2003). Soil erosion and the global carbon budget. Environment international, 29(4), 437-450.

[6] Field, D. J., Koppi, A. J., Jarrett, L. E., Abbott, L. K., Cattle, S. R., Grant, C. D., ... & Weatherley, A. J. (2011). Soil science teaching principles. Geoderma, 167, 9-14.

[7] Nouhou Bako, A., Darboux, F., James, F., Josserand, C., & Lucas, C. (2016). Pressure and shear stress caused by raindrop impact at the soil surface: Scaling laws depending on the water depth. Earth Surface Processes and Landforms, 41(9), 1199-1210.

[8] Ben-Hur, M., & Agassi, M. (1997). Predicting interrill erodibility factor from measured infiltration rate. Water Resources Research, 33(10), 2409-2415.

[9] Rousseva, S., Lazarov, A., Tsvetkova, E., Marinov, I., Malinov, I., Kroumov, V., & Stefanova, V. (2006). Bulgaria. Soil erosion in Europe, 167-181.

[10] Sanchis, M. S., Torri, D., Borselli, L., & Poesen, J. (2008). Climate effects on soil erodibility. Earth Surface Processes and Landforms: The Journal of the British Geomorphological Research Group, 33(7), 1082-1097.

[11] Singh, M. J., & Khera, K. L. (2008). Soil erodibility indices under different land uses in lower Shiwaliks. Tropical Ecology, 49(2), 113.

[12] Wilke, B.-M., Horn, R. (2010): Bodenerosion, in: Scheffer, F., Schachtschabel, P., Blume, H.-P. (Bearb.): Lehrbuch der Bodenkunde Scheffer Schachtschabel, 16. Ed. Spektrum, Akademischer Verlag, Heidelberg/Berlin, p. 506-513; 511, 512.

[13] Heckrath, G., Djurhuus, J., Quine, T.A., Van Oost, K., Govers, G., Zhang, Y. (2005) Tillage erosion and its effects on soil properties and crop yield in Denmark. J. Environ. Qual. 34, 312-324; 312.

[14] Van der Knijff, J. M. F., Jones, R. J. A., & Montanarella, L. (1999). Soil erosion risk assessment in Italy. European Soil Bureau, European Commission.

[15] Wang, B., Zheng, F., Römkens, M. J., & Darboux, F. (2013). Soil erodibility for water erosion: A perspective and Chinese experiences. Geomorphology, 187, 1-10.
[16] Bagarello, V., Di Stefano, C., Ferro, V., Giuseppe, G., & Iovino, M. (2009). A pedotransfer function for estimating the soil erodibility factor in Sicily. Journal of Agricultural Engineering, 40(3), 7–13.
[17] Renard, K. G., Foster, G. R., Weesies, G. A., McCool, D. K., & Yoder, D. C. (1997). Predicting soil erosion by water: a guide to conservation planning with the revised universal soil loss equation (RUSLE). agriculture handbook no. 703 (p. 384)US Department of Agriculture, Agriculture Research Service 384.
[18] Atalay, I (1997): Türkiye Coğrafyası. Ege Üniversitesi Basımevi Bornova,. Izmir
[19] Balci, A.N. (1971): Influence of Parent Material and Slope Exposure on Properties of Soils Related to Erodibility in North Central Anatolia. Mitteilungen der Deutschen Bodenkundlichen Gesellschaft, Bd.131, Heft 1, p.42-55.
[20] Zech, W., Cepel, N. (1977): Anatolien – ein bodengeographischer Streifzug. Sonderdruck aus den Mitteilungen der Geographischen Gesellschaft in München. Band 62.
[21] Çanga, M., Erpul, G. (1994): Toprak İşlemeli Tarım Alanlarında Erozyon ve Kontrolü. Topraksu, 3(2), 14-16.
[22] Wischmeier, W.H., Smith, D.D. (1978): Predicting Rainfall Erosion Losses Guide to Conservation, Agricultural Handbook 537. Planning, Science and Education Administration. US Dep. of Agriculture, Washington, DC, USA. P. 58.
[23] Özden, S., Özden, D.-M. (1998): Turkey erosion estimation model-Turtem, International symposium on arid region soils and land, Izmir, Turkey.
[24] Bayramin, I., Dengiz, O., Başkan, O., Parlak, M. (2003): Soil Erosion Risk Assessment with ICONA Model, Case Study: Beypazarı Area. Turkish Journal of Agriculture and Forestry, 27,105-116.
[25] Irvem, A., Topaloğlu, F., Uygur, V. (2007): Estimating Spatial Distribution of Soil Loss Over Seyhan River Basin in Turkey. Journal of Hydrology, 336: 30-37.
[26] Tunç, E., Schröder, D. (2010): Determination of the Soil Erosion level in Agricultural lands in the western part of Ankara by USLE. Ekoloji 19, 75, 58-63.
[27] Schwertmann, U., Vogl, W., Kainz, M. (1987): Bodenerosion durch Wasser: Vorhersage des Abtrags und Bewertung von Gegenmaßnahmen. Ulmer, Stuttgart.
[28] Innominate (1992): Gaziantep İli Arazi Varlığı, Tarım ve Köy İşleri Bakanlığı, Köy Hizmetleri Genel Müdürlüğü Yayınları, İl Rapor No: 27 s: 26-28, Ankara.
[29] Schlichting, M., Blume, E. (1966): Bodenkundliches Praktium. Verlag Paul Pary, Hamburg an Berlin.
[30] Richards, L.A. (1954): Diagnosis and improvement of saline and alkali soils. US Salinity Lab., US Department of Agriculture Handbook 60. California, USA.

[31] Kretzschmar, R., (1991): Kulturtechnisch-bodenkundliches Praktikum. Ausgewählte Laboratoriumsmethoden. Eine Anleitung zum selbstständigen Arbeiten an Böden, 7. Aufl. Selbstverlag, Univ. Kiel.

[32] Allison, L.E., Moodie, C.D. (1965): Carbonate. In: Black, C.A. [ed.]: Methods of Soil Analysis. Part 2. Chemical and Microbiological Properties. American Society of Agronomy, Madison, pp. 1379-1396.

[33] Lindsay, W.L., Norvell, W.A. (1978): Development of a DTPA Soil Test for Zinc, Iron, Manganese and Copper. Soil Sci. Amer. Jour., 42 (3): 421-428.

[34] Jackson, M. (1958): Soil chemical analysis. Prentice-Hall, Inc. Englewood Cliffs, New Jersey, USA. p. 1-498.

[35] Schmidt, J. (1996): Entwicklung und Anwendung eines physikalisch begründeten Simulationsmodells für die Erosion geneigter landwirtschaftlicher Landflaechen. Berliner Geographische Abhandlungen, Heft, 61.

[36] Hartge, K.H. & Horn, R. (1989): Die physikalische Untersuchung von Böden. 2. Aufl., Enke, Stuttgart, Germany.

[37] Sekera, F., Brunner, A. (1943): Beiträge zur Methodik der Gareforschung. Bodenkunde und Pflanzenernährung 29, 169-212.

[38] AG Boden (2005): Bodenkundliche Kartieranleitung. 5th edn., Schweizerbart'sche Verlagsbuchhandlung, Stuttgart.

[39] Çimrin K.M., Boysan, S. (2006): Nutrient Status of Van Agricultural Soils and Their Relationships with Some Soil Properties. Yüzüncü Yıl Üniversitesi, Ziraat Fakültesi, Tarım Bilimleri Dergisi (J. Agric. Sci.), 16(2): 105-111.

[40] FAO (1990): Micronutrient, Assessment at the Country Level: An International Study. FAO Soil Bulletin by Sillanpaa. Rome.

[41] Auerswald, K., Kainz, M., Angermüller, S. (1996): Influence of exchangeable potassium on soil erodibility. In: Soil Use and Management 12, S.117-121.

[42] Cihacek LJ (1999): Restoring productivity of eroded soils with manure applications, NDSU Dickinson Research and Extension Center Annual Report 1999.

[43] Whalen, J.K., Chang, C. (2002): Macroaggregate characteristics in cultivated soil after 25 annual manure applications. Soil Science and. Society, 66, 1637-1647.

[44] Koch, H.-J., Heuer, H., Tomanová, O., Märländer, B. (2008): Cumulative effect of annually repeated passes of heavy agricultural machinery on soil structural properties and sugar beet yield under two tillage systems. Soil Till. Res. 101, 69–77.