Socio-economic modifications of the Universal Soil Loss Equation

A. Erol[1], Ö. Koşkan[2], M. A. Başaran[3]
[1]SDÜ Faculty of Forestry, Department of Watershed Management, Isparta,
aytenerol@sdu.edu.tr (corresponding author)
Phone:+90246 211 3988
Fax: +90246 237 1810
[2]SDÜ Agricultural Faculty, Department of Biometric Genetics, Isparta
[3]Western Mediterranean Forestry Research Institute, Antalya

Abstract. While social scientists have long focused on socio-economic and demographic factors, physical modelers typically study soil loss using physical factors. In the current environment, it is becoming increasingly important to consider both approaches simultaneously for the conservation of soil and water, and the improvement of land use conditions. This study uses physical and socio-economic factors to find a coefficient that evaluates the combination of these factors. It aims to determine the effect of socio-economic factors on soil loss and, in turn, to modify the Universal Soil Loss Equation (USLE). The methodology employed in this study specifies that soil loss can be calculated and predicted by comparing the degree of soil loss in watersheds, with and without human influence, given the same overall conditions. A coefficient for socio-economic factors, therefore, has been determined based on adjoining watersheds (WS I and II), employing simulation methods. Combinations of C and P factors were used in the USLE to find the impact of their contributions on soil loss. The results revealed that these combinations provided good estimation of soil loss amounts for the second watershed, i.e. WS II, from the adjoining watersheds studied in this work. This study shows that a coefficient of 0.008 modified the USLE to reflect the socio-economic factors as settlement influencing the amount of soil loss in the studied watersheds.

Keywords: erosion; USLE; socio-economic factors; physical factors; adjoining watersheds

1 Introduction

Soil erosion is a natural process for landscape development if accelerated denudation processes by human impact. Moreover, it determines the landscape and the landforms, the soil and water quality, the vegetation recovery and the fate of the societies (Zhao et al., 2013). This phenomenon is a globally environmental threat that reduces the productivity of all natural ecosystems (Kertész, 2009; Pimentel and Burgess, 2013; Leh et al., 2013) including soil where the adaptation capacity is weak (Cerdà, 2000; Leh et al., 2013). Pimentel (1993) numerically stated that between 30 and 50 per cent of the world's arable land is significantly degraded by soil erosion. Additionally, erosion-induced soil quality deterioration is prevalent all over the world (Harden, 2001; Zhao et al., 2013) obstructing the global food source and socio-economic security. Young (1993) indicated that the challenges of soil erosion are more severe in the heavily populated, under-developed, and ecologically fragile areas of the world. Lal (1981) and Eswaran et al. (2001) asserted that misuse of soils, resulting from a desperate attempt by farmers to increase production for the growing population aggravates soil quality degradation. Tesfahunegn (2013) further claims that severity of such degradation is higher in developing countries where the economy mainly depends on agriculture.

Soil erosion, which is one of the primary issues that forestry and agriculture agencies have to deal with, is a critical problem in Turkey. The current population of Turkey is 76.7 million (TUİK, 2014), and the land surface area is 78 million ha; this comprises 36% of agricultural land, 27.6% of rangeland, and 29.8% of forest and shrub cover, with the remaining 6.5% of land accounting for settlements and water bodies (OSİB, 2005). To put it bluntly, it is anticipated that there will be a dramatic increase in settlements due to rapid population growth which results in intensive construction in the mountainous areas of which especially used for agriculture and forest. Indeed, soil erosion is a key issue in mountainous regions worldwide (Leh et al., 2013; Mandal and Sharda, 2013; Haregeweyn et al., 2013; Wang and Shao, 2013). Mountain soils develop in very sensitive environments subject to natural and anthropic disturbances (e.g. Cerdà and Lasanta, 2005; Vanwalleghem et al., 2011; Van der Waal et al., 2012; García Orenes et al., 2012), and they are often located at the interface with densely settled areas, which may be considerably affected by sediment release from upstream erosion (Ziadat and Taimeh, 2013; Cao et al., 2014;

Lieskovský and Kenderessy, 2014). Similarly, watersheds of Turkey are located at mountainous areas and these areas mainly under the effect of soil erosion impact water quality and quantity. Furthermore, land use management practices are becoming increasingly important due to growth in improper land use in the country and existing considerable spatial heterogeneity in terms of land use and management, topography, and socio-economic conditions all over Turkey.

Land degradation and especially soil erosion have long interval been studied for physical processes such as geography, geology, agronomy, and engineering using USLE (Boardman et al., 2013). USLE proceeds to be the most widely used model for soil loss estimations. Several studies have been performed in India (Ali and Sharda, 2005; Sharda and Ali, 2008; Narain et al., 1994) and other countries (Van Rompaey et al., 2002; Larsonm et al.,1997) to estimate the performance of the USLE in predicting soil loss under different situations (Mandal and Sharda, 2013). Besides, in eastern Himalayan region potential soil erosion rates for different states of the region were estimated by collecting data on various parameters of USLE by Mandal and Sharda, 2013. However, Castro et al. (2001) criticized that the USLE has limited applications. In the present study were tried to find a coefficient to modify the USLE, instead of the RUSLE that is a better and revised version of the USLE. The main reason of that data from previous studies was obtained from the USLE that is the most commonly model used in Turkey. It is obvious that the use of RUSLE would be more perfect to achieve better results when in a similar study designed using actual data.

Jayarathne et al. (2010) established that there is a strong positive relationship between land degradation and soil erosion, as well as land degradation and population density. Strong negative relationships were also observed between land degradation and land/man ratio. Boardman et al. (2003) stated the physical and socio-economic factors drive soil erosion; therefore, these factors need to be addressed in tandem. However, it is often the case that the studies on this subject are not given in an interdisciplinary fashion (Boardman et al., 2003). Given this view, evaluating physical factors with socio-economic factors is the best starting point for determining the degree of soil loss using two different disciplines. Additionally, Evans (1996) made an attempt with his assessment of the socio-economic and physical drivers, impacts and costs of erosion for UK and Wales. On the other hand, few studies have evaluated both physical and socio-economic factors, using the effects of settlements in the USLE method. However, Veldkamp and Lambin, (2001) states that the incorporation of socio-economic drivers of land use change is critical for the accurate representation of land use change. Besides, as pointed out by Verburg et al. (2004), the integration of social, political, policy and economic factors into land use change modeling are often not successful because of difficulties in quantifying socio-economic factors and integrating such data with other environmental data (Leh et. al., 2011).

In the present study, socio-economic factors were spatially considered as settlements including humans and animal shelters. Thus, cropping management (C factor) and erosion control practice (P factor) were used to estimate the contribution of socio-economic factors in the USLE (Wischmeier and Smith, 1962, 1965, 1978; Lal, 1994). In addition, a calculation method was suggested to determine a coefficient that would consider the interactions of physical and socio-economic factors using a simulation method. The amount of soil loss resulting from human and animal influence in settlements was calculated using simple mathematical equations. Using this method, a coefficient that could distinguish between settlements, which consists of both humans and animals, and physical factors affecting erosion, was incorporated into the USLE for two small watersheds with the similar characteristics.

In this study, we hypothesized the presence of settlements in the study area, where the impact on erosion in the USLE depended on the number of people and animals due to their settlements. The main objective is to determine the amount of erosion arising from these factors, thus, to ascertain the contribution of these factors within the USLE.

2 Materials And Methods

2.1 Description of the Study Area

Two small adjoining watersheds (36° 54.074′ N; 30° 31.536′ E) covering areas of 700 and 800 ha, respectively, located in a small Mediterranean Watershed in Antalya, western Turkey (Figure 1), were selected as the study areas. Thus, these watersheds with similar properties allow comparison with each other (Özhan, 2004). Hereafter, the watersheds were referred to as WS I and WS II; some of their features are described in Table 1. Additionally, open forest was a forest area not characterized by productive forest cover, due to destruction. Therefore, these forest areas were considered as dense and open forests in two adjoining watersheds.

Figure 1. Location of the study area in Antalya, Turkey

Table 1. Selected features of WS I and WS II obtained from GIS and past references (Doğan and Güçer, 1976; Arnoldus, 1977; Balcı, 1996; Cebel et al., 2013)

Land uses of WS I are dense forest, open forest and lake constituting 630.4 ha, 60.4 ha, and 9.2 ha that comprise of 90.08%, 8.68% and 1.31% of the total area, respectively. The total area of WS I is encompassed forest trees and other vegetation types. The cover layer of WS I (i.e., 700 ha) is 68% (Table 1).

WS II includes dense forest (408 ha), open forest (8 ha), lake (2 ha), orchard (255 ha), agriculture (68 ha), settlement (11 ha), and greenhouse (48 ha), which consist of 51%, 1%, 0.25%, 31.88%, 8.5%, 1.38%, and 6% of the total area in the watershed, respectively. The cover layer in the watershed is 40% and the total area of the watershed (800 ha) encompassed with forest trees and various types of vegetation. Altitude of the watersheds are 664 m and 316 m, respectively. Soil group and texture of the watersheds are Red Mediterranean Soil and clay loam (Table 1).

2.2 Data from GIS, Previous Studies, and Use in USLE

The USLE is used in Turkey as the most common mathematical model for predicting the amounts of soil loss in forests and rangelands. Previously, Turkey has been studied primarily with reference to the R, C, and P factors in the model (Doğan and Güçer, 1976; Çanga, 2006).

The topographic features such as L, S, evaluation, aspect, etc., and land use data of the present study were obtained using GIS and other data such as soil group and factors in the USLE, which used to determine a coefficient in the USLE were obtained from previous studies (Doğan and Güçer, 1976; Arnoldus, 1977; Balcı, 1996; Cebel et al., 2013). Figure 2 shows the working steps of factors in USLE to determine soil loss with USLE integrated in GIS (Fistikogli & Harmancioglu 2002). Parameters before the step D.E.M such as land covers and after the step D.E.M such as aspects, slopes, and LS factor were mathematically calculated by GIS to determine the amount of soil loss for the watersheds.

In addition, precipitation amounts were obtained from a single station, which was close to the two watersheds (Table1). The reason of that there are no sufficient meteorological stations which are both representing the watersheds. Therefore, precipitation amounts (1076.7 mm) were taken from only one station nearest to the both watersheds (Table 1).

In the present study, slope length (l) and slope steepness (s) factors used to calculate L and S in the USLE were also obtained using GIS (Table 1). R factor, K factor (Table 1) were provided from data of previous studies obtained in the same area by Doğan and Güçer (1976), Arnoldus (1977), Balcı (1996) and Cebel et al. (2013). WS I was found to have experienced almost no human impacts, whereas WS II suffered from intensive human impacts. K factor representing the Red Mediterranean Soils (0.12) was used owing to the surface depth of the soil (Cebel et al., 2013) both in WS I and WS II. The soil group as the one was the moderately erodible soils for both WS I and WS II (Doğan and Güçer, 1976) (Tables 1). Data relating to L and S of l and s (Tables 1) were determined to calculate equations from previous studies (Equations 1 and 2) (Balcı, 1976).

Table 1. Soil erodibility factor (K) in terms of soil group, topographic, and land use data for WS I* from GIS and past references. Red Mediterranean soils (T); slope length factor (l); and slope steepness factor (s).

Table 2. Cropping management (C) and erosion control practice (P) factors for WS I and WS II (adapted from Balcı, 1996)

The values for the C and P factors reported by Balcı (1996) were determined for a study area with properties identical to those of the existing study described here; accordingly, they were considered to be most appropriate for use in this study (Table 2). The USLE can be presented as follows:

$$A = KRLSCP \qquad (1)$$

where, (A) is the annual soil loss (ton/ha/year). In Equation (1), the impacts of slope length and steepness were usually combined into one single factor (Randle et al., 2003), known as the topographic factor (LS) (Balcı, 1996), which can be computed as follows:

$$LS=l^{0.5}(0.0136+0.00965\,s+0.00138\,s^{2}) \quad (2)$$

s (%) and l (m) calculated to the LS factor for the studied watersheds were 1.32 for WS I and 0.714 for WS II (Table 3). As can be seen in these tables, the K, R, C, and P factors established in the USLE for dense forests, open forests, orchards, and agricultural lands in both watersheds were obtained from previous studies (Doğan and Güçer, 1976; Arnoldus, 1977; Balcı, 1996; Doğan et al., 2000; Cebel et al., 2013). Finally, all the factors of the USLE were used to determine the total annual soil loss (Table 3). It has been established that the K, R, L and S factors were represented in a distinct layer in the USLE (LIFE+ Programme, 2011), which explains why the potential and actual erosion amounts were not calculated for comparison (Table 3). It is well known that actual erosion values cannot be calculated for settlements and greenhouses. This is because these areas do not have enough vegetation cover to influence the calculations. The USLE can only be used to calculate actual erosion values; however, potential erosion calculations do not take into account land use and vegetation. As the two values cannot be compared, potential erosion values used for settlement and greenhouse areas.

Table 3. Factors affecting the USLE and the soil loss amounts for WS I. Rainfall factor (R); soil erodibility factor (K); topographic factor (LS); cropping management factor (C); and erosion control practice factor (P).

2.3 Data Analysis

The available soil loss amounts and the degree of socio-economic factors for each of the watersheds were calculated with considering previous studies. Thus, it was expected that a coefficient could be added to the current USLE equation. A simulation method was used based on FORTRAN programming.

All data of the study area were used to evaluate the contributions of the socio-economic factors to the total annual erosion (A) and find a coefficient in USLE. C and P values for the socioeconomic factors in the USLE were obtained from the average of C and P values taking their total of all existing values. In other words, to the coefficient for socioeconomic factor as settlement were found using all C and P values to obtain an average value. Subsequently, C and P factors were analyzed to find their averages. The contributions of socio-economic factors to the total annual soil loss amounts were established. In the process, simple mathematical equations were used to find the coefficient (Figure 3). These steps were shown on a flow chart modified from Fistikogli and Harmancioglu (2002) to check over the USLE and soil loss estimation, and finally mathematical processes to find a coefficient.

Figure 2. Flow chart to estimate a coefficient using USLE in the study

The calculation of the factors affecting soil loss amounts for WS I was completed using the traditional USLE, because this watershed was assumed not to be under the influence of any human impact. However, the annual amount of soil loss in WS II was determined using both physical factors used in the USLE and the modified coefficient in the USLE.

The sequence of calculation steps aimed to generate the required coefficient. Accordingly, each progression was defined separately as follows;

The total number of people and animals in the settlements were described as the socio-economic factor (Se); it was used to estimate the amount of soil loss in the settlement (Se_E). This equation used the ratio of settlement numbers in total watershed area (ha) multiplied by the amount of soil loss (A) from the USLE (Step 1). The second process was stated as effect of socioeconomic factors (Soc-e-F_E), which was the amount of soil loss due to socio-economic factors were calculated using the amount of soil loss per person (Pp_E = Se_E / total Pp) and per animal (An_E = Se_E /total An) (Step 2) to find the contribution of socio-economic factors as settlements in A (ton/ha/year) (Step 3). The ratio of (Soc-e-F_E) to A gave the coefficient (Step 4). This coefficient also represented the total C and P values contributing to the averages of the available C and P used in the study (Figure 3).

Figure 3. Steps for calculating the USLE coefficient that represents the contribution of socio-economic factors to soil loss.

3 Results and Discussion

The total area and altitude of the WS I and WS II were 700 ha and 800 ha, and 664 m and 316 m, respectively. In addition, slope was 27,43% in WS I and 14,82 in WS II (Table 1). Crown closure of WS I was found 40-70% and 20-35% for WS I and WS II, respectively. Although vegetation covers except for the lake areas in WS I and WS II were 68% and 40%, respectively (Table 1). We assumed that there was almost no human impact on WS I, howerever, WS II had an intensive human impact. Though, it should be accepted that the dense forest changed into the open forest by illegal logging, which can be called a human impact. The previous studies (Doğan and Güçer (1976), Balcı (1996) and Cebel et al. (2013) had also assumed that open forest already included illegal logging. According to even if only this data, it should be expected that the amount of soil loss in WS II would be considerably more than in WS I even though it had the lower percentage of slope. Similarly, dead cover on soil in WS I was 75-85%, although in WS II was 40-70% (Table 2 and 3). Therefore, C and P factors for WS I and WS II was selected as 0.025-0.14 and 1.0 (without erosion control management practices)-0.40 (with erosion control management practices) from previous studies. In this case, it was expected that the amount of soil loss in WS I could be less than WS II due to vegetation cover and structure. Zhongming et al. (2010) also stated that vegetation cover has an important role since the rate of soil erosion decreases as the vegetation cover increases. It also roles reduce the erosive impact of precipitation that is the same in both watersheds. For all that, LS in WS I and WS II was 1.31 and 0.714, respectively. This means that undoubtedly the steeper and longer the slope, the higher the risk for erosion in WS II. Besides, P factor in WS II was 0.40 that it would definitely result in lower soil loss (Table 1 and 2). In addition to all these, terraces and tillage methods used such as terraces and contours in Agriculture and Orchard land uses probably reduced the slope length and increased soil water moisture in WS II that they would result in lower soil losses (USDA, 2011) and higher water moisture in those for WS II and for Open Forest in WS I because of vegetation residues and contours.

In the present study was considered the number of humans and livestock in terms of affecting the amount of soil loss in WS II. These values, which consisted of 2,650 people and 3,100 livestock according to the 2007 census year (Source: oral communication with Muharrem Akman who is the village headman), were used to calculate their effects or contribution to the amount of soil loss as socio-economic factors in the area. Boardman et al. (2003) stated that the socio-economic, such as human population and livestock, contributed to soil loss and physical factors drive soil erosion.

Data analysis was conducted in order to estimate to contribution of settlements as coefficient to WS I and WS II. At the first stage, all mentioned data was used to estimate to actual erosion, except for Settlement and Greenhouse areas due to no have vegetation cover, using USLE. After this stage, human and livestock impacts per unit of the amount of soil loss were established in the equation. Then the contribution of settlement on the total amount erosion of soil was identified by measuring kg. At the end of this stage, the amount of soil loss was calculated using USLE for WS I and WS II. All different C and P factors in the equation were simulated with combinations of them. After then, the means of the coefficients for each of combination with the amount of soil loss was determined. The means of these coefficients were identified as the correction coefficient of socio-economic factors, which contribute to the amount of soil loss in USLE. The range of determining the coefficient through simulation was developed as a mathematical equation. The coefficient, which can be added as a correction coefficient, was calculated as 0.008. Therefore, the modified coefficient with USLE can be represented as $0.008A + A$ that had the correction coefficient was determined and stated as $\pm SE = 0.008 \pm 0.000944$. This means that the rate of 0.8% could be increase or decrease the rate of 0.000944 (± 11,8% of the coefficient).

The calculated results of similar land uses in selected two watersheds showed that Dense Forests and Open Forests in the total area were 90,06%-51% in WS I and 8,63% -1% in WS II while the amount erosion of those soils was 0,658 t/ha/yr-3,683 t/ha/yr in WS I and 0,7115 t/ha/yr-6,4034 t/ha/yr in WS II using USLE (Table 3). Besides, the amount of soil loss using modified coefficient that was 0.08% were 0,663 t/ha/yr-3,712 t/ha/yr in WS I while 0,7172 t/ha/yr-6,4546 t/ha/yr in WS II (Table 4). The results showed that the increase from modifying coefficient was 0.005 -0,029 t/ha/yr in WS I while 0.0057 t/ha/yr-0.05123 t/ha/yr in WS II, respectively (Tables 3 and 4). Although these increases may seem less per ha, considering the increase in the total area of each land use may be understood that the amount of soil loss would be very much in both watersheds. In addition, the amount of soil loss in Orchard (225 ha) and Agricultural land (68 ha) was found 7,364 t/ha/yr and 0,0171 t/ha/yr in WS II, respectively. As mentioned above, the total amount erosion of soils for Settlements (11 ha) and Greenhouses (48 ha) were calculated as potential erosion owing to the lack of vegetation cover in these land uses (LIFE+ Programme, 2011; Savacı, 2012). The amount erosion of their soils were calculated as 1072,83 t/yr and 4681,44 t/yr using l and s (13.5 m and 14.82%), respectively. This result also shows that vegetation cover plays a very important role due to land use surface. Jones et al. (2004) stated that its role is a factor mitigating soil erosion by surface water. Mandal and Maiti (2015) also stated that land use and land cover play a significant role to influence surface run off and slope material saturation. Besides, it was stated that socio-economic demand of the local people would aggravate the problems of soil loss and slope failure. According to the researchers surface water is an indicator of potential erosion and instability. In this context, it is possible and likely that forest and open forest areas of WS II might be damaged in case of more settlements due to more erosion problems. Changes in the amount of soil loss determined with the new equation in the present study were considered to be the result of human and animal's settlements. The values of the amount of soil loss with the modified coefficient in the USLE are symbolized in Figure 4. Unquestionably, the amount of soil loss from USLE depended on biophysical factors as well as socio-economic factors interacting with other factors such as cropping management (C) and erosion control practice (P) factors, however, in previous studies were not considered human population and livestock numbers as erodible factors in USLE. In view of the above lack, these erodible factors as called settlement in the present study were used to find a coefficient. As Okun et al. (1989) clearly pointed out that settlements are connected to ecological systems and environmental services because the exploitation of natural resources directly impacts economical life line of the communities and ecological support of their system and sustainability of their communities. Considering that the sustainability of watersheds containing these socio-economic factors, there is a need to understand their contribution to erosion in USLE. Jingan et al. (2005) and Halim et al. (2007) reported that biophysical factors contributed about 65% to erosion, while socio-economic factors accounted for about 35%. The coefficient showed that socio-economic factors evaluated in the present study affect the amount of soil loss in the watersheds, even if only slightly (Table 4). Undoubtedly, all factors change depending on biophysical conditions of watersheds such as topography, soil properties and climate as well as their socio-economic factors. Therefore, in the present study determined coefficient represents just WS II.

Table 4. Soil loss amounts without socio-economic factors in the USLE and with the modified coefficients

4 Conclusions

The settlement area in WS II is very small, such that the contribution of socio-economic factors appears limited. Admittedly, 0.8% of the increase could be very minimal. However, it is highly possible that the amount of soil loss would increase in large settlement areas. It could be accepted that coefficient is a safety factor for WS II due to its unique properties. The decisions of the local authorities should be considered in this context, since Antalya is a resort area, however, a densely populated with a terrible air temperature in the summers. Hence, there are an increasingly tendency to build settlements in the mountainous areas. Therefore, it is highly likely that risk of soil loss in mountainous areas described as plateau would increase in the future.

There is a need to improve existing methods to estimate the amount loss of soil. This approach will be studied to obtain coefficients representing all socio-economic factors in many watersheds. Thence, it will be possible to develop a new method that allows reducing soil erosion risks and improving watershed management plans.

References

Ali, S. and Sharda, V. N.: Evaluation of the Universal Soil Loss Equation (USLE) in semi-arid and sub-humid climates of India. Applied Engineering in Agriculture, 21, 217-25, 2005.

Arnoldus, H. M. J.: Predicting soil losses due to sheet and rill erosion, FAO Conservation Guide 1, Guidelines for Watershed Management, FAO, Rome, 1977.

Balcı, N.; Soil Conservation, Istanbul University Faculty of Forestry, Department of Watershed Management, University Publication No: 3947, Faculty Publication No: 439, ISBN 975-404-423-6, Istanbul [In Turkish], 1996.

Boardmana, J., Poesen, J. and Evans, R.: Socio-economic factors in soil erosion and conservation, Environmental Science and Policy 6: 1–6, doi: 10.1016/S1462-9011(02)00120-X, 2003.

Brevik, E. C., Cerdà, A., Mataix-Solera, J., Pereg, L., Quinton, J. N., Six, J., and Van Oost, K.: The interdisciplinary nature of soil, soil, 1: 117-129, doi:10.5194/soil-1-117-2015, 2015.

Cao, L., Zhang, K., Dai, H., and Liang, Y.: Modeling interrill erosion on unpaved roads in the Loes Plateau of China, Land Degradation and Devevelopment, doi:10.1002/ldr.2253, 2014.

Castro, F. C., Cochrane, T. A., Norton, L. D., Caviglione, J. H. and Johansson, L. P.: Land degradation assessment: tools and techniques for measuring sediment load, Agric. Research Service, Purdue University, West Lafayette, USA, 2001.

Cebel, H., Akgül, S., Doğan, O. and Elbaşı, F.: K factors of erosion sensitivity of Turkey soil groups, Journal of Soilwater, 2 (1): 30-45, 2013.

Cerdà, A. and Lasanta, T.: Long-term erosional responses after fire in the Central Spanish Pyrenees: Water and sediment yield, Catena, 60, 59-80, doi:10.1016/j.catena.2004.09.006, 2005.

Cerdà, A.: Aggregate stability against water forces under different climates on agriculture land and scrubland in southern Bolivia, Soil Till. Res., 36, 1-8, 2000.

Çanga, M.: Soil Erosion [in Turkish] available at:http://www.agri.ankara.edu.tr/soilscienc (last access: 4 December 2014), 2006.

Doğan. O., Cebel, H., Küçükçakar, N. and Akgül, S.: K factors of erosion sensitivity of Turkey Soil Groups, Prime Ministry General Directorate of APK Department of Rural Services, Research Directorate of Soil and Water Resources, Publication No. 111, Guide No. 17, Ankara [in Turkish], 2000.

Doğan, O. and Güçer, C.: The causes of water erosion-formation and determining of soil loss using Universal Soil Loss Equation, Ministry of Village Works, General Directorate of Soilwater, Central of Soilwater Research Institute Publications, General Publication No. 41, Technical Publication No. 24, Ankara, 1976.

Erol. A. and Serengil Y.: A historic journey to prevention and estimation of erosion, Turkey Science and Technology Congress (Oral Presentation), 30–31 October 2006, Isparta [in Turkish], Turkey, 2006.

Eswaran, H., Lal, R. and Reich, P. F.: "Land Degradation: An Overview" in Bridges, E.M., I.D. Hannam, L.R. Odeman, F.W.T. Pening de Vries, S. J.. Scherr, and S. Sompatpanit (Eds.), Responses to Land

Degradation, Proc. 2nd International Conference on Land Degradation and Desertification, Khon Kaen, Thailand, Oxford Press, New Delhi, India, 2001.

Evans, R.: Soil erosion and its impacts in England and Wales, Friends of the Earth, London, 1996.

Feoli, E., Vuerich L. G. and Zerihun W.: Evaluation of environmental degradation in northern Ethiopia using GIS to integrate vegetation, geomorphological, erosion and socio-economic factors, Agriculture, Ecosystems and Environment, 91, 313–325, 2002.

Fistikogli, O., Harmancioglu, N. B.: Integration of GIS with USLE in assessment of soil erosion, Faculty of Engineering, Dokuz Eylul University, Izmir, Turkey, 2002.

Foley, J. A., Ramankutty, N., Brauman, K. A., Cassidy, E. S., Gerber, J. S., Johnston, M., Mueller, N. D., O'Connell, C., Ray, D. K., West, P. C., Balzer, C., Bennett, E. M., Carpenter, S. R., Hill, J., Monfreda, C., Polasky, S., Rockström, J., Sheehan, J., Siebert, S., Tilman, D., and Zaks, D. P. M.: Solutions for a cultivated planet, Nature, 478: 337-342, 2011.

García-Orenes, F., Roldán, A., Mataix-Solera, J., Cerdà, A., Campoy, M., Arcenegui, V., and Caravaca, F.: Soil structural stability and erosion rates influenced by agricultural management practices in a semi-arid Mediterranean agro-ecosystem, Soil Use Management, 28, 571-579, doi:10.1111/j.1475-2743.2012.00451.x, 2012.

Halim, R., Clemente R. S., Routray J. K. and Shrestha R. P.: Integration of biophysical and socio-economic factors to assess soil erosion hazard in the upper Kaligarang watershed, Indonesia, Land Degradation and Development, 18, 453-469, doi: 10.1002/ldr.774, 2007.

Harden, C. P.: Soil erosion and sustainable mountain development: experiments, observations, and recommendations from the Ecuadorian Andes, Mt. Res. Dev., 21, 77-83, 2001.

Haregeweyn, N., Poesen, J., Verstraeten, G., Govers, G., de Vante, J., Nyssen, J., Deckers, J. and Moeyersons, J.: Assessing the performance of a spatially-distributed soil erosion and sediment delivery model (WATEM/SEDEM) in northern Ethiopia, Land Degradation and Development, 24 (2), 188-204, 2013.

IPCC (Intergovernmental Panel on Climate Change): Climate Change 2007: Working Group II: Adaptation and Vulnerability, Fourth Assessment Report: Climate Change 2007, Content: 3.4.5: Erosion and Sediment Transport, "available at: https://www.ipcc.ch/publications_and_data/ar4/wg2/en/ch3s3-4-5.html, 2007".

Jayarathne, K. D. B. L., Dayawansa, N. D. K., De Silva, R. P.: GIS based analysis of biophysical and socio-economic factors for land degradation in Kandaketiya DS, Division, Tropical Agricultural Research, 21(4), 361-367, 2010.

Jingan, S., Jiupai, N., Chaofu, W. and Xie Deti, W.: Land use change and its corresponding ecological responses: A review, Journal of Geographical Sciences, 15 (3), 305-328, 2005.

Kertész, Á.: The global problem of land degradation and desertification, Hungarian Geographical Bulletin, 58, 19–31, 2009.

Lal, R. Deforestration of tropical rainforest and hydrological problems, R. Lal and Russell E. W. (Eds.) Tropical agricultural hydrology, 131-140, J. Willey and Sons, Chichester, UK, 1981.

Lal, R.: Soil erosion research methods (Ed.), St Lucie Press. Delray Beach FL 33483 USA, 1994.

Larson, W. E., Lindstrom, M. J. and Schumacher, T. E.: The role of severe storms in soil erosion: A problem needing consideration, Journal of Soil and Water Conservation, 52, 90-95, 1997.

Leh, M. D. K.: Quantification of sediment sources in a mixed land use watershed: A remote sensing and modeling approach, PhD Thesis, University of Arkansas: Fayetteville, AR, 2011.

Leh, M., Bajwa, S., and Chaubey, I.: Impact of land use change on erosion risk: and integrated remote sensing geopraphic information system and modeling methodology, Land Degradation and Development, 24, 409-421, doi:10.1002/ldr.1137, 2013.

Lieskovský, J. and Kenderessy, P.: Modelling the effect of vegetation cover and different tillage practices on soil erosion in vineyards: a case study in Vráble (Slovakia) using WATEM/SEDEM, Land Degradation and Development, 25, 288-296, doi:10.1002/ldr.2162, 2014.

LIFE+ Programme (European Commission): Soil Erosion Risk USLE Model, Explanation of the Data and Model of Soil Erosion Uploaded in the Sicilian Framework of the SMS, LIFE08ENV/IT/000428, available at: http://www.soilpro.eu/assets/doc.html (last access: 28 December 2014), 2011.

MacGillivray, C. M. I.: A relative potential erosion detection (PED) model for the upper Buff Bay catchment, parish of Portland, Jamaica: A Geographical Information System application (prepared for publication by S.K. Donovan), "available at: http://www.repository.naturalis.nl/document/45041, 2007".

Mandal, D. and Sharda, V. N.: Appraisal of soil erosion risk in the Eastern Himalayan Region of India for soil conservation planning, Land Degradation and Development, 24(5), 430-437, doi: 10.1002/ldr.1139, 2013.

Narain, P., Khybri, M. L., Tomar, H. P. S. and Sindhwal, N. S.: Estimation of runoff, soil loss and USLE parameters for Doon Valley, Indian Journal of Soil Conservation, 22, 1-9, 1994.

Nearing, M. A, Pruski F. F, O'Neal, M. R.: Expected climate change impacts on soil erosion rates: A review, Journal of Soil and Water Conservation, 59 (1), 43-50, 2004.

Okun, D., Crosson, P., Cummings, B., Braatz, S., Wilson, M., and Eigen, J (Eds.).: Natural resources in regional development, in Guidelines for settlements planning and management, Environmental Consideration in Regional Planning and Management (III), 83-473 www. https://books.google.com.tr,1989.

OSİB (Ministry of Environment and Forests).: Turkey's National Action Programme to Combat Desertification, Unit of National Coordination for Combat Desertification, Ministry of Environment and Forests Publications No. 250, ISBN 975-7347-51-5, Ankara, available at:

http://www.cevreorman.gov.tr [in Turkish] (last access: 6 December 2014), 2005.

Özhan, S.: Watershed Management, Istanbul University Faculty of Forestry, Department of Watershed Management, IU Rectorate Publication No: 4510, Faculty Publication No: 481, ISBN 975-404-739-1, 313, Istanbul [in Turkish], 2004.

Pimentel, D.: World Soil Erosion and Conservation, Cambridge University Press: Cambridge, 1993.

Pimentel, D. and Burgess, M.: Soil erosion threatens food production, Agriculture, 3, 443-463, 2013.

Randle, T. J, Yang, C. T. and Daraio, J.: Erosion and Reservoir Sedimentation, Chapter 2, 1-94, available at: http://www.usbr.gov/pmts/sediment/kb/Chapter2.pdf (last access: 19 December 2014), 2003.

Savacı, G.: Determination of Erosion Risk Maps According to Corine Methodology of Goz and Haman Watersheds in Kahramanmaras, Kahramanmaras Sutcu Imam University Graduate School of Natural and Applied Science, Master's Thesis, Kahramanmaras, available at: http://www.irfanakar.com/turkish/pdf2 [in Turkish] (last access: 28 December 2014), 2012.

Sharda, V. N. and Ali, S.: Evaluation of the Universal Soil Loss Equation in semi-arid and sub-humid climates of India using stage-dependent C-factor, Indian Journal of Agricultural Sciences, 78, 422-427, 2008.

Tesfahunegn, G. B.: Soil quality indicators response to land use and soil management systems in northern Ethiopia's catchment, Land Degradation and Development, doi:10.1002/ldr.2245, 2013.

TUIK (Turkish Statistical Institute): Key Indicators: Population of Turkey (2013), "available at: http://www.tuik.gov.tr [In Turkish] (last access: 25 December 2014), 2014.

Udo, R. K, Areola, O. O, Ayoade, J. O. and Afolayan, A. A.: Nigeria: Regional study of transformation in B. L. Turner II et al., (Eds,) The Earth as transformed by human action, Cambridge University Press, 589-603, 1990.

USDA (The U.S. Department of Agriculture).: National Agronomy Manual, 190-V-NAM, 4thEd,www.nrcs.usda.gov/wps/PA_NRCS Consumption/download, 2011.

Van der Waal, B. W., Rowntree, K. M., and Radlof, S. E.: The effect of Acacia mearnsii invasion and clearing on soil loss in the Kouga Mountains, Eastern Cape, South Africa, Land Degradation and Development, 23, 577-585, doi:10.1002/ldr.2172, 2012.

Van Rompaey, A. J. J. and Govers, G.: Data quality and model complexity for continental scale soil erosion modelling, International Journal of GIS, 16, 663-680, 2002.

Vanwalleghem, T., Infante Amate, J., González de Molina, M., Soto Fernández, D., and Gómez, J. A.: Quantifying the e_ect of historical soil management on soil erosion rates in Mediterranean olive orchards, Agriculture, Ecosystems and Environment, 142, 341-351, doi:10.1016/j.agee.2011.06.003, 2011.

Veldkamp, A. and Lambin, E. F.: Predicting land-use change, Agriculture, Ecosystems and Environment, 85, 1-6, 2001.

Verburg, P. H., Schot, P. P., Dijst, M. J. and Veldkamp, A.: Land use change modelling: Current practice and research priorities, GeoJournal, 61, 309-24, 2004.

Wang, Y. Q. and Shao, M. A.: Spatial variability of soil physical properties in a region of the loess plateau of PR China subjet to wind and water erosion, Land Degradation and Development, 24, 296-304, doi:10.1002/ldr.1128, 2013.

Wessels, K. J.: Letter to the editor: Comments on "Proxy global assessment of land degradation" by Z. G. Bai et al. (2008), Soil Use Management, 25, 91-92, doi:10.1111/j.1475 2743.2009.00195.x, 2009.

Wilson, E. O.: The diversity of life, New York: W.W. Norton, 1992.

Wischmeier, W. H. and Smith, D. D.: Soil-Loss Estimation as a Tool in Soil and Water Management Planning, Institute of Association of Scientific Hydrology, Publication No. 59, pp. 148–159, 1962.

Wischmeier, W. H. and Smith, D. D.: Predicting Rainfall-Erosion Losses from Cropland East of the Rocky Mountains, U.S. Department of Agriculture, Agriculture Handbook No. 282, 48, 1965.

Wischmeier, W. H. and Smith, D. D.: Predicting Rainfall Erosion Losses-Guide to Conservation Planning, U.S. Department of Agriculture, Agriculture Handbook No. 537, 1978.

Young, A.: Land degradation in South Asia: its severity, causes, and effects upon the people, Final report, Economic and Social Council, FAO, UN, Rome, 1993.

Zhao, G., Mu, X., Wen, Z., Wang, F. and Gao, P.: Soil erosion, conservation, and eco-environment changes in the Loess Plateau of China. Land Degradation and Development, 24, 499-510, doi: 10.1002/ldr.2246, 2013.

Ziadat, F. M. and Taimeh, A. Y.: Effect of rainfall intensity, slope and land use and antecedent soil moisture on soil erosion in an arid environment, Land Degradation and Development, 24, 582-590, doi:10.1002/ldr.2239, 2013.

Table 1. Selected features of *WS I and WS II obtained from GIS and previous studies, and soil erodibility factor (K) in terms of Soil Group, some data from GIS and previous studies* of WS I and WS II. Red Mediterranean soils (T); slope length factor (l); and slope steepness factor (s).

Study area features	WS I	WS II
Location	Antalya Center	Antalya Center
Area (ha)	700 ha	800 ha
Annual Precipitation (mm)	1076.7 mm	1076.7 mm
Altitude	664	316
Vegetation Cover (%)	68 (except lake)	40 (except lake)
*Soil Group	Red Mediterranean Soils (T)	Red Mediterranean Soils (T)
*Texture	Clay Loam	Clay Loam
Human Impact	Almost no human impact	Human impact
*K Factor		
(0–15 cm)	0.12	0.12
Total Area (ha)	700	800
Dense Forest (ha)	630,4	408
Open Forest (ha)	60,4	8
Lake (ha)	9,2	2
Orchard (ha)	---	255
Agriculture (ha)	---	68
Settlements (ha)	---	11
Greenhouse (ha)	---	48
Aspect	Southeast	Southeast
Length	4100	3765
22,1		22,1
185,5204^0,5		170,362^0,5
s (%)	27,63	14,82
Max. Length	1230	1230
Min. Length	97	37
Difference L	1133	558
l (m)	13,62	13,05

Table 2. Cropping management (C) and erosion control practice (P) factors for WS I (adapted from Arnoldus (1977) and Balcı (1996)

WS I	Dense Forest (630.4 ha)	Features Mid-frequency, 40-70% crown closure, dead cover 75–85% of the soil cover, status of the flora of the soil cover. Not Protected (Arnoldus, 1977). P: 1.0 (no erosion control practice)
	Open Forest (60.4 ha)	Sparse forests or trees deprived of short bushes, 50% coverage, 40% closure of soil surface P: 0.40 (vegetation residues on the soil strips and tillage toward contours)
WS II	Dense Forest (408ha)	Often sparse, 35–20% crown closure, dead cover 40-70% of the soil cover, status of the flora of the soil cover. Not Protected (Arnoldus, 1977). P: 1.0 (no erosion control practice)
	Open Forest (60.4 ha)	Adequate bush or shrub, 25% coverage, closure rate of 20% of the soil surface P: 1.0 (no erosion control practice)
	------------	-------------------------
	Orchard (255 ha)	Rare trees, coverage 25%, covering the soil surface flora 20% P: 0.90 (agriculture on contours)
	Agriculture (68 ha)	Tall grasses (Fabaceae) closure 50%, 95% of the soil surface cover P: 0.16 (terracing and agriculture on contours)
	Settlements (11 ha)	Coverage 15%, 100% of the soil close (without C and P factors)
	Greenhouse (48 ha)	Coverage 90%, 100% of the soil close (without C and P factors)

Table 3. Factors affecting the USLE and the amount of soil loss for WS I. Rainfall factor (R); soil erodibility factor (K); topographic factor (LS); cropping management factor (C); and erosion control practice factor (P).

Watershed	Land Use	R	K	LS	C	P	A (t/ha/yr)	Total soil loss amounts in terms of land use (t/yr)
WS I	Dense Forest (ha)	415.2	0.12	1.32	0.01	1.0	0.658	414.80
	Open Forest (ha)	415.2	0.12	1.32	0.14	0.40	3.683	222.45
WS II	Dense Forest (408 ha)	415.2	0.12	0.714	0.02	1.0	0.7115	8449.68
	Open Forest (8 ha)	415.2	0.12	0.714	0.18	1.0	6.4034	1490.88
	Orchard (255 ha)	415.2	0.12	0.714	0.23	0.90	7.364	54651.60
	Agriculture (68ha)	415.2	0.12	0.714	0.003	0.16	0.0171	33.80
								Potential erosion
	Settlement (11 ha)	415.2	0.12	l: 13.05 s: 14.82%	---	---	---	1072.83
	Greenhouse (48 ha)	415.2	0.12	l: 13.05 s: 14.82%	---	---	---	4681.44

Table 4. The amount of soil loss without and with modified coefficient in the USLE

WS I	Area (ha)	The amount of soil loss without socio-economic factors in USLE (t/ha/yr)	The amount of soil loss with modified coefficient in USLE (t/ha/yr)	Difference between two amount erosion of soil (ton/ha/year) and contribution of coefficient (%)
		A (t/ha/yr)	0.008A +A	(0.008A+A)-A
Dense Forest	630.4	0.658	0,663	0,005
Open Forest	60.4	3.683	3,712	0,029
WS II	Area (ha)	A (t/ha/yr)	0.008A +A	(0.008A+A)-A
Dense Forest	408	0.7115	0,7172	0.0057
Open Forest	8	6.4034	6,4546	0,05123
Orchard	255	7.364	7,423	0,05891
Agriculture	68	0.0171	0,01724	0,000137