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Socio-economic modifications of the Universal Soil Loss Equation

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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 watersheds studied.

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 % 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 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. Thus, their soils are very sensitive to soil erosion. 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.

Foley et al. (2011) made a global emphasis on the soil erosion problem that the global population is predicted to reach 9 billion by 2050; in combination with changes in dietary behavior, a large net increase in productivity and/or agricultural area is needed. Additionally, Brevik et al. (2015) argued that soils are thus under increasing environmental pressure, and this will have consequences for the capacity of the soil to continue to perform its variety of functions. Environmental degradation from human pressures and land use has become a major worldwide problem (Wilson, 1992), however, the effects are felt more in developing countries due to the high population growth rate and the associated rapid depletion of natural resources (Feoli et al., 2002). According to Udo et al. (1990) soils are impoverished and may have also been destroyed by erosion in very densely populated areas. Similarly, on the national level, soil erosion is expected to increase (Nearing et al., 2004; IPCC, 2007). Thus, amelioration measures should be taken in all countries especially at the regional and national level.

However, some studies declared the extent, severity, and consequences of soil degradation remain poorly documented (Bai et al., 2008; Wessels, 2009), there is a vital need for quantitative, repeatable measures of degradation (Brevik et al., 2015) and/or soil loss. Since biodiversity loss, soil degradation or soil loss and changing in climate are now gradually related to food security, water security, energy security, biodiversity, and many ecosystem services such as food, water and energy security, biodiversity, this critical phenomenon is an international problem. The high rate of erosion under human influences therefore has necessitated the determination of soil loss caused by socio-economic factors and other environmental drivers in order to identify and implement sustainable management practices.

The methodology used to combat soil erosion requires an understanding of the mechanisms and consequences of the phenomenon of erosion itself. However, in order to manage erosion at the national level, it is vital to act with a specific and strategic plan in terms of the rational use of natural resources (Erol and Serengil, 2006). In this

SED
7, 1731–1759, 2015

context, the most efficient approach for minimizing erosion problem is thought to be the use of resources in a timely and organized manner. Haregeweyn et al. (2013) stated that critical erosion hotspots are defined as parts of watersheds with high erosion rates. These hydrological units are also under the influence of human activity including socio-economic factors causes changing the character of the watershed. On the other hand, determining the influential socio-economic “causes” of erosion is just as complex. Furthermore, data to be determined causes of erosion is very scarcely limited. According to MacGillivray (2007), many of the political and socio-economic factors, however, are regionally effective and intangible. On the other hand, it is important to assess the degree of soil erosion under different environmental and socio-economic situations in order to identify and apply suitable land management interventions (Castro et al., 2001) understand the causes and effects of soil erosion. Therefore, there is a need for more research on the relationship between cause and effect of erosion. Haregeweyn et al. (2013), however, signified that spatial data to determine soil erosion in the developing countries is often scarce and possibilities to identify source areas for erosion and sediment are very limited. As a matter of fact, Turkey also should be considered to be one of them.

Land degradation and in particular, soil erosion, has long been studied as a physical process by scientists using USLE from backgrounds as a diverse as geography, geology, agronomy, and engineering (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 regionpotential 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, the USLE is often criticized for its limited applications (Castro et al., 2001), and inability to recognize the cause-effect factors on erosion or the amount of soil

SED
7, 1731–1759, 2015

loss. 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.

SED
7, 1731–1759, 2015

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. The objective is to determine if any of these factors contribute to erosion, and how much the factors would influence the outcome of 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 (Fig. 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 II; some of their features are described in Table 1.

Of the total area of WS I (i.e., 700 ha), 98.63 % is covered with dense forests, open forests, and lakes, but 68 % of the total area of dense forest and open forest included forest trees and other vegetation types. Additionally, open forest was a forest area not characterized by productive forest cover, due to destruction. Therefore, these forest areas were labeled as dense and open forests in the two adjoining watersheds. Land uses in WS I covered dense forest, open forest, and lakes, constituting 630.4, 60.4, and 9.2 ha, respectively. The land uses in WS II were dense forest, open forest, lake, orchard, agricultural land, settlement, and greenhouse, which accounted for 408, 8, 2, 255, 68, 11, and 48 ha, respectively, of the total area of the watershed (800 ha). Of the total area, 92.35 % of WS II was covered with dense forest, open forest, lake, orchard, agriculture, settlement, greenhouse and 40 % of these areas were covered with various types of vegetation (Table 1).

All data for this study, such as topographic features, were obtained from GIS; the effects of the physical and socio-economic factors used to determine the USLE coefficient were obtained from the past references (Doğan and Güçer, 1976; Arnoldus, 1977; Balcı, 1996; Cebel et al., 2013).

2.2 Data from GIS and past references

The topographic features and land use data of the two adjoining watersheds were obtained using GIS methods and the topographic data of the watersheds (Tables 1–3). Slope length (l) and slope steepness (s) factors, used to calculate L and S in the USLE, were also obtained using GIS (Table 2 and 3). Soil erodibility (K factor), rainfall (R factor) (Table 2 and 3), cropping management (C factor), and erosion control practices (P factor) (Tables 4 and 5) were provided from data of the past references (Doğan and Güçer, 1976; Arnoldus, 1977; Balcı, 1996; Cebel et al., 2013). In the study, WS I was found to have experienced almost no human impact, whereas WS II suffered from intensive human impact. K factor of 0.12 was used owing to the surface depth of the soil and represented Red Mediterranean Soils (Cebel et al., 2013) both in WS I and II. R factor (415.2) was used owing to the presence of Red Mediterranean Soils and the moderately erodible soils for both WS I and II (Doğan and Güçer, 1976) (Tables 2 and 3). Data relating to L and S of l and s (Tables 2 and 3) used in the USLE were determined using equations from past references (Eqs. 1 and 2) (Balcı, 1976).

2.3 Data obtained for the 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 C and P factors for the watersheds were adapted from past references (Balcı, 1996), and many other previous studies were investigated in terms of the various USLE factors. 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 (Tables 4 and 5). The USLE can be presented as follows:

$$A = \text{KRLSCP}, \quad (1)$$

where (A) is the annual soil loss ($\text{t ha}^{-1}\,\text{year}^{-1}$). In Eq. (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:

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

s and l calculated to the LS factor for the studied watersheds were 1.32 for WS I and 0.714 for WS II (Tables 6 and 7). As can be seen in these tables, the K, R, C, and P factors established for the USLE for dense forests, open forests, orchards, and agricultural lands in both watersheds were obtained from the past references (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 (Tables 6 and 7). 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 8). 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.

2.4 Data analysis

The available soil loss amounts and the degree of socio-economic factors for each of the watersheds were calculated with considering the past references. 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 the physical data of the study area were obtained using GIS, and 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 a 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. These steps are detailed in Table 8.

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 settlement were the socio-economic factor (Se); it was used to find the amount of soil loss in the settlement (Se_E). The equation used the ratio of settlement numbers to total watershed area (ha) multiplied by the amount of soil loss (A) from the USLE (Step 1).

The second process was stated as (Soc-e-F_E), which was the amount of soil loss due to socio-economic factors. This result was calculated using the amount of soil loss per person and per animal (Step 2 and 3).

Step (1) and (3) was taken to find the contribution of socio-economic factors in A ($\mathrm{t\,ha^{-1}\,year^{-1}}$) (Step 4).

The ratio of (Soc-e-F_E) to A gave the coefficient. This coefficient also represented the total C and P values contributing to the averages of the available C and P used in the study.

SED
7, 1731–1759, 2015

3 Results and discussion

The amount of soil loss in WS I was found to be 0.658 t ha^{-1} $year^{-1}$ per ha of dense forest, but this value was 414.803 t ha^{-1} $year^{-1}$ for the total area of dense forest (630.4 ha) in the watershed. Soil loss amounts were calculated per ha of open forest (3.683) and were found to be 222.453 ton/60, 4 ha $year^{-1}$ using the USLE (Table 6). According to the factors that affect the USLE, soil loss amounts according to land use in WS II were as follows: 0.7115 per ha of dense forest; 6.4034 per ha of open forest; 7.364 per ha of orchard; and 0.0171 per ha of agricultural land. The total soil loss amounts for the total area of land use in the watershed were as follows: 8449.68 t ha^{-1} $year^{-1}$ dense forests; 1490.88 t ha^{-1} $year^{-1}$ open forest; 54 651.60 t ha^{-1} $year^{-1}$ orchards; and 33.80 t ha^{-1} $year^{-1}$ agricultural lands. Total soil loss amounts for settlements and greenhouses were calculated as potential erosion owing to the lack of vegetation cover in these land uses (LIFE+ Programme, 2011; Savacı, 2012).

After establishing human and livestock impacts per unit of soil loss amount, the contribution of settlement land on the total soil loss amount could be identified (measured in kg). Consequently, the soil loss amounts were calculated with the total soil loss amount of the USLE. This coefficient was also simulated with different C and P factor combinations and the mean of the coefficients for each of the C and P factors combinations with total soil loss was determined. The means of these coefficients were identified as the correction coefficient of socio-economic factors, which contribute to the total soil loss in the USLE.

The coefficient, which can be added as a correction coefficient, was calculated as 0.008. The modified USLE can be represented as follows:

$$0.008A + A. \quad (3)$$

The correction coefficient is determined as follows:

$$\pm SE = 0.008 \pm 0.000944, \quad (4)$$

where (A) is the USLE output ($\mathrm{t\,ha^{-1}\,year^{-1}}$) and SE is the settlement land area (ha). The range of the determined coefficient, through simulation, is developed mathematical equation with the coefficient is shown in Table 10.

There are very few studies on this issue. Halim et al. (2007) studied the integration of biophysical and socio-economic factors in assessing erosion hazard; they found seven key hazard factors; of which five were biophysical factors: soil texture (silt content), maximum rainfall erosivity (I30), slope (LS-factor), land cover (C factor), soil conservation practices (P-factor); and two were socio economic factors: farmer's perception on erosion and income).

In this study, it was considered that all factors in the USLE affect erosion; however, the contribution of the socio-economic factors, evaluated as settlements with human and livestock, affected only a small amount of the soil loss in the USLE. The R factor (415.2) for Red Mediterranean Soil (T) (Doğan and Güçer, 1976) and K factor ($0.10 < K < 0.20$) for moderately erodible soils (Cebel et al., 2013) were used to calculate erosion amounts from USLE in the watershed located at Antalya, Turkey. Unquestionably, the erosion amount from USLE depended on these factors interacting with other factors such as cropping management (C) and erosion control practice (P) factors, but did not consider human population and livestock numbers. To understand these socio-economic factors there is a need to understand their contribution in the USLE. 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 study, affect soil erosion in the watershed, even if only slightly. According to our results, physical and socio-economic factors contributed approximately 99.2 and 0.8 %, respectively (Table 9). Undoubtedly, all factors change depending on the watersheds and their topographical conditions and soil properties (biophysical factors) as well as their socio-economic factors (Jingan et al., 2005; Halim et al., 2007).

The study presents the number of humans and livestock in WS II. These values, which consisted of 2650 people and 3100 livestock according to the 2007 census year

SED
7, 1731–1759, 2015

(Source: village headman, Muharrem Akman, personal communication, 2015), were used to calculate their effects or contribution to the total soil erosion as socio-economic factors in the area. Boardman et al. (2003) stated that the socio-economic and physical factors drive soil erosion. It was considered that socio-economic factors, such as human population and livestock, contributed to soil loss.

Changes in soil loss, determined with the new equation, were considered to be the result of human and animal settlements. The values of the soil loss amounts with the modification coefficient in the USLE are represented in Table 9.

4 Conclusions

In this study, variations in soil loss due to settlements including humans and livestock have been determined for watershed named WS II. The settlement area in this watershed is very small, such that the contribution of socio-economic factors appears limited. It is highly possible that soil loss would increase in large settlement areas. The findings of this study demonstrate that investigation of many watersheds are required to ensure a wider applicability of these findings and determine more reliable coefficients that can be incorporated into the USLE. In this context, many different watersheds in order to compare with each other should be studied with this approach and more data should be gathered regarding the socio-economic factors of the watersheds in Turkey.

Admittedly, the resulting correction factor relative conventional USLE amounts to just 0.8 % is not enough to evaluate impacts of the settlement on the soil loss for the watershed used in this study. We estimate that the most important reason of this is to ratio of settlements in the entire watershed is too small. However, since Antalya is a resort area and increasingly prone to settlements in the mountainous areas, it is highly likely that risk of soil loss will increase in the future.

It is well known that there is a need to improve existing methods for the estimation of soil loss, especially in developing countries such as Turkey, which are facing with soil erosion and which have both rough mountains and sensitive soils. The result of this

SED
7, 1731–1759, 2015

study should be used to improve the method employed in this approach by the large number of watersheds in Turkey.

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SED
7, 1731–1759, 2015

Socio-economic modifications of the Universal Soil Loss Equation

A. Erol et al.

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Table 1. Selected features of Watersheds I and II obtained from GIS and the past references.

Study area features	Watershed I	Watershed II
Location	Antalya Center	Antalya Center
Area (ha)	700 ha	800 ha
Annual Precipitation (mm)	1076.7 mm	1076.7 mm
Land Use	Forest, open forest, lake	Forest, open forest, lake, orchard, agriculture, settlements, greenhouse
Elevation (m)	664	316
The total ratio of land use (%)	98.63	92.35
Vegetation Cover (%)	68 (except lake)	40 (except lake)
Soil Group and Texture	*Red Mediterranean Soils (T), Clay Loam	*Red Mediterranean Soils (T), Clay Loam
Human Impact	Almost no human impact	Human impact

* The past references.

SED
7, 1731–1759, 2015

Table 2. Soil erodibility factor (K) in terms of Soil Group and some data from GIS and the past references of Watershed I[a]. Red Mediterranean soils (T); slope length factor (l); and slope steepness factor (s).

Location	Soil[b] Group	K Factor[b] (0–15 cm)	Total Area (ha)	Forest (ha)	Open Forest (ha)	Lake (ha)	Aspect	l (m)	s (%)
Antalya Center	T	0.12	700	630.4	60.4	9.2	south-east	Length: 4100	Max. Length: 1230
								22.1	Min. Length: 97
								$185\,5204^{0.5}$	Difference L: 1133
								13.62	27.63

[a] Watershed with almost no human impacts.
[b] The past references.

SED
7, 1731–1759, 2015

Table 3. Soil erodibility factor (K) in terms of Soil Group and some data from GIS and the past references of Watershed II[a]. Red Mediterranean soils (T); slope length factor (l); and slope steepness factor (s).

Location	Soil[b] Group	K Factor[b] (0–15 cm)	Total Area (ha)	Dense Forest (ha)	Open Forest (ha)	Lake (ha)	Orchard (ha)	Agri-culture (ha)	Settle-ments (ha)	Green-house (ha)	Aspect	*l* (m)	*s* (%)
Antalya Center	T	0.12	800	408	8	2	255	68	11	48	south-east	Length: 3765	Max. Length: 1230
												22.1	Min. Length: 37
												$170\,362^{0.5}$	Difference L: 558
												13.05	14.82

[a] Watershed with intensive human impact.
[b] The past references.

SED
7, 1731–1759, 2015

Table 4. Cropping management (C) and erosion control practice (P) factors for Watershed I (adapted from Balcı, 1996).

Location	Dense Forest (ha)	Features of Forest	C Factor	P Factor	Open Forest (ha)	Features of Open Forest	C Factor	P Factor
Antalya Center	630.4	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)	0.025	1.0 (Not taking any preservative measures)	60.4	Sparse forests or trees deprived of short bushes, 50 % coverage, 40 % closure of soil surface	0.14	0.40

Table 5. Cropping management (C) and erosion control practice (P) factors for Watershed II (adapted from Balcı, 1996).

Location	Dense Forest (ha)	Features of Forest	C Factor	P Factor	Open Forest (ha)	Features of Open Forest	C Factor	P Factor
Antalya Center	408	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).	0.055	1.0 (Not taking any preservative measures)	8	Adequate bush or shrub, 25 % coverage, closure rate of 20 % of the soil surface	0.18	1.0 (Not taken any preservative measures)
	Orchard (ha)	Rare trees, coverage 25 %, covering the soil surface flora 20 %	0.23	0.90 (plough in contour line)	Agriculture (ha)	Tall grasses (Fabaceae) Closure 50, 95 % of the soil surface cover	0.003	0.16 (agriculture in leveling curve)
	2				255			
	Settlements (ha)	Coverage 15, 100 % of the soil close	–	1.0 (Not taking any preservative measures)	Greenhouse (ha)	Coverage 90, 100 % of the soil close	–	1.0 (Not taking any preservative measures)
	68				11			

SED
7, 1731–1759, 2015

Socio-economic modifications of the Universal Soil Loss Equation

A. Erol et al.

Table 6. Factors affecting the USLE and the soil loss amounts for Watershed I. Rainfall factor (R); soil erodibility factor (K); topographic factor (LS); cropping management factor (C); and erosion control practice factor (P).

Watershed I	Land Use	R Factor	K Factor	LS Factor	C Factor	P Factor	*A* ($t\,ha^{-1}\,year^{-1}$)	Total soil loss amounts in terms of land use ($t\,ha^{-1}\,year^{-1}$)
Total Area (ha) 700	Dense Forest (ha) 630.4	415.2	0.12	1.32	0.01	1.0	0.658	Forest 414.80
	Open Forest (ha) 60.4	415.2	0.12	1.32	0.14	0.40	3.683	Open Forest 222.45
Total Annual Soil Loss Amounts	4.341							637.26

SED
7, 1731–1759, 2015

Table 7. Factors affecting the USLE and the soil loss amounts for Watershed II. Rainfall factor (R); soil erodibility factor (K); topographic factor (LS); cropping management factor (C); and erosion control practice factor (P).

Water-shed II	Land Use	R Factor	K Factor	LS Factor	C Factor	P Factor	A (t ha^{-1} year^{-1})	Total soil loss for total land use area (t ha^{-1} year^{-1})
Total area (ha) 800	Dense Forest (ha) 408	415.2	0.12	0.714	0.02	1.0	0.7115	Forest 8449.68
	Open Forest (ha) 8	415.2	0.12	0.714	0.18	1.0	6.4034	Open Forest 1490.88
	Orchard (ha) 255	415.2	0.12	0.714	0.23	0.90	7.364	Orchard 54 651.60
	Agriculture (ha) 68	415.2	0.12	0.714	0.003	0.16	0.0171	Agriculture 33.80
	Settlement (ha) 11	415.2	0.12	l: 13.05 s: %14.82	–	–	–	Settlement (potential erosion) 1072.83
	Greenhouse (ha) 48	415.2	0.12	l: 13.05 s: %14.82	–	–	–	Greenhouse (potential erosion) 4681.44

* Total annual soil loss amounts = 64 624.96.

SED
7, 1731–1759, 2015

SED
7, 1731–1759, 2015

Table 8. The stages to decide a coefficient using USLE which represents the contribution of socio-economic factors impact on soil loss.

Sequence	Mathematical process	The result of each process
1	Se_E = A (Se/Wha)	The amount of soil loss in the settlements
2	Pp_E = Se_E/total Pp	The amount of soil loss from per person
	Apn_E = Se_E/total Apn	The amount of soil loss from per number of animals
3	Soc-e-F_E = Pp_E + Apn_E	The amount of soil loss of socio-economic factors
4	Se_E_c = Soc-e-F/Se_E	The contribution in the amount of soil loss of the settlements
5	Soc-e-F_E/A= Coefficient = ∑P + ∑C values/ ∑P + ∑C numbers	Coefficient which corresponding to the average value of all P and C factors impacted on socio-economic factors

Table 9. Soil loss amounts without socio-economic factors in the USLE and with modified coefficient with the relative differences.

Watershed I Land Use	Area (ha)	Soil loss amounts without socio-economic factors in the USLE ($t\,ha^{-1}\,yr^{-1}$)	Soil loss amounts with modified coefficient in the USLE ($t\,ha^{-1}\,yr^{-1}$)	Difference between them ($t\,ha^{-1}\,yr^{-1}$) and contribution of coefficient (%)
		A	$0.008A + A$	$(0.008A + A) - A$
Dense Forest	630.4	10.35	10.4328	0.0828
Open Forest	60.4	16.57	16 703	0.133
Watershed II	Area (ha)	A	$0.008A + A$	$(0.008A + A) - A$
Forest	408	20.71	20, 876	0.166
Open Forest	8	186.36	187, 851	1.491
Orchard	255	214.32	216, 035	1, 715
Agriculture	68	0.497	0.501	0.004
Settlement	–	–	–	–
Greenhouse	–	–	–	–

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SED

7, 1731–1759, 2015

Socio-economic modifications of the Universal Soil Loss Equation

A. Erol et al.

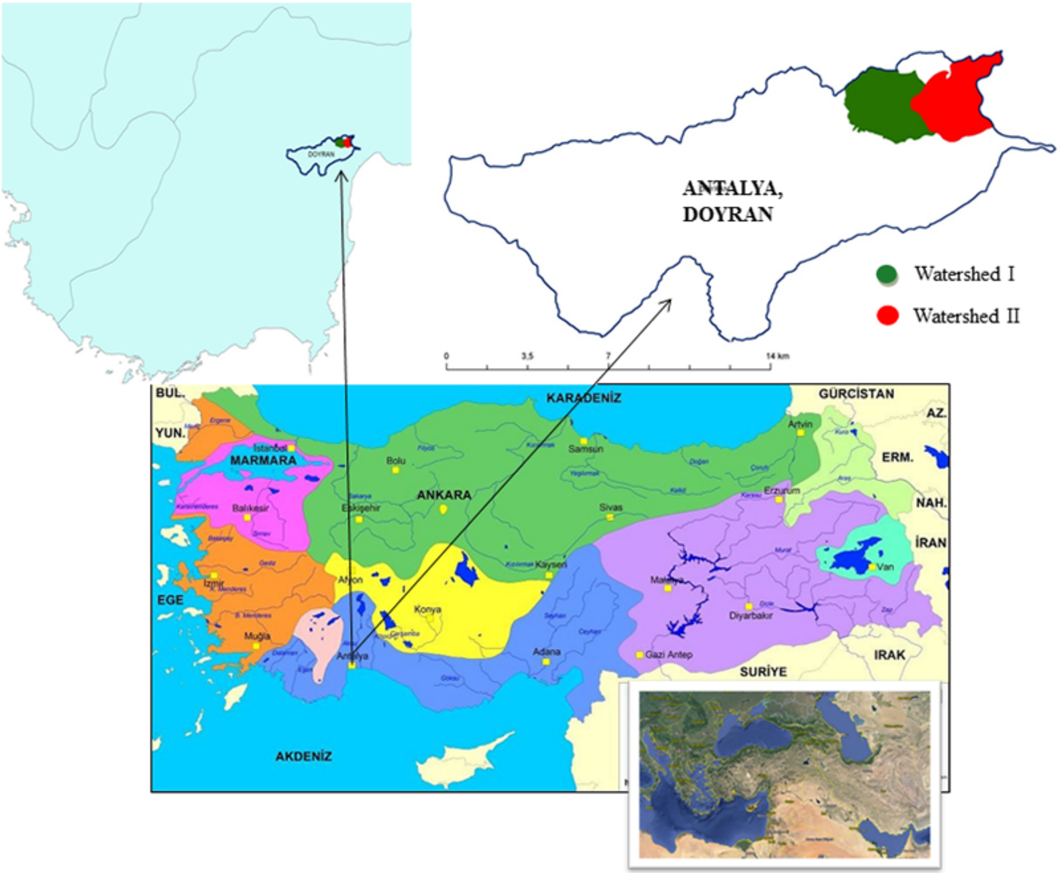

Figure 1. Location of the study area in Antalya, Turkey.

SED
7, 1731–1759, 2015

Socio-economic modifications of the Universal Soil Loss Equation

A. Erol et al.

Title Page
Abstract Introduction
Conclusions References
Tables Figures
◀ ▶
Back Close
Full Screen / Esc
Printer-friendly Version
Interactive Discussion