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ORIGINAL RESEARCH PAPER

Impact of land use change on soil erodibility

F. Taleshian Jeloudar, M. Ghajar Sepanlou, S.M. Emadi*

Department of Soil Sciences, Faculty of Crop Sciences, Sari Agricultural Sciences and Natural Resources University, Sari, Iran

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ABSTRACT: Vulnerability of soil separates to detachment by water is described as soil erodibility by Universal Soil Loss Equation which can be affected by land use change. In this study it was attempted to quantify the changes of Universal Soil Loss Equation K-factor and its soil driving factors in three land uses including rangeland, rainfed farming, and orchards in Babolrood watershed, northern Iran. Soil composite samples were obtained from two layers in three land uses, and the related soil physico-chemical properties were measured. The rainfed farming land use showed the highest clay contents, but the highest amounts of soil organic matter and sand particles were found in orchard land use. The high intensity of tillage led to the significant decrease of soil aggregate stability and permeability in the rainfed farming land use. The Universal Soil Loss Equation K-factor was negatively correlated with soil permeability ($r=-0.77^{**}$). In rangeland, the K-factor (0.045 Mg h/MJ/mm) was significantly higher and the particle size distribution had a great impact on the K-factor. The orchard land use, converted from the rangeland, did not show any increase of soils erodibility and can potentially be introduced as a good alternative land use in sloping areas. However, more detailed studies on environmental, social and economic aspects of this land use are needed.

KEYWORDS: *Erodibility; Land use change; Rangelands; Soil loss; Universal Soil Loss Equation (USLE).*

INTRODUCTION

Soil erosion is known as an important economic, environmental and social disaster (Wang *et al.,* 2013). Soil erosion is described as detachment and removal of surface particles from soil as a result of wind or rainfall. Soil loss is a worldwide concern, which threatens soil and water resources (Morgan, 2004). Soil, as the most important component of an ecosystem, can secure the food production, enhance the water resources and promote the biodiversity and carbon sequestration (Novara *et al.,* 2016) if it is well managed (Mol and Keesstra, 2012; Keesstra *et al.,* 2016). The main parameter in soil erosion is the inherent soil characteristics, which is called soil erodibility factor. Type and rate of soil erosion/loss in an area depend on different factors including climate, geomorphology, soil type and land use. Considering the different factors involved in soil loss, the land use is the most important one due to the potential destructive role of human effects. Land use change and agricultural development cause large changes to soil characteristics which make soils susceptible to erosion and degradation (Szilassi *et al.,* 2006). Land use change has an adverse effect on soil characteristics such as permeability, soil texture and aggregate stability (Szilassi *et al.,* 2006; Emadi *et al.,* 2008; Emadi *et al.,* 2009). Changes of these characteristics are important because they lead to change in the rate of soil erodibility (Lambin and Geist, 2008). Some researchers also showed that change of land use from forest to croplands may result in clay and silt increase and sand decrease (Bewket and Stroosnijder, 2003; Martinez-Mena *et al.,* 2008). This could be

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*Corresponding Author Email: *mostafaemadi@gmail.com*
Tel.: +9811 3368 7568 Fax: +9811 3368 7568

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attributed to the selective detachment of soil particles and decomposition of organic carbons related to the instability of soil aggregates. In this regard, investigation of the organic carbon impact on soil parameters denoted that application of organic carbon had a positive effect on water holding capacity and soil porosity, leading to reduction of soil erodibility reduction (Evrendilek *et al.,* 2004). Soil erosion in agricultural land use has a pronounced impact on the source and amount of sediment in the river. Morgan (2004) demonstrated that the conversion of pasture to farmlands accelerated the soils erosion on a watershed scale. Soil loss rate in Iran has been calculated as 25 Mg/ha/y (Afshar *et al.,* 2010). To forecast soil loss rate, several equations have been prepared. The Universal Soil Loss Equation (USLE) model is a well-known methods which is extensively used to predict and determine the factors affecting soil loss (Lal, 1988; Wischmeier and Smith 1978; Devatha *et al.,* 2015). The USLE model is a simple empirical model which has been developed based on multiplying five erosion factors including soil erodibility (K-factor), soil erosivity (R), topography (LS), land cover (C) and practice (P). As already mentioned, soil erodibility is the most impressive factor for assessing the soil susceptibility to erosion and it is necessary for estimating soil loss in USLE (Wischmeier, 1979). Although the USLE has been widely used to predict K-factor in many studies (Vaezi *et al.,* 2008; Vaezi *et al.,* 2010; Shabani *et al.,* 2014), it may not be applicable to all soils with different soil forming processes. The L and S as inherent landscape characteristics cannot be changed easily by anthropogenic activities, unless there are soil conservation practices. The R, C, and P are dependent on weather conditions and anthropogenic activities. Therefore, the K-factor is more strongly related to soil physical characteristics. The accurate evaluation of K-factor for development of soil management strategy is crucial. Organic carbon (OC) content is crucial for determination of soil erodibility that can be severely affected by land use change (Emadi *et al.,* 2009). Impacts of land use change on soil OC, permeability and aggregate stability (Celik, 2005; Emadi *et al.,* 2009) can led to the changes in the inherent soil erodibility. Rodrigo Comino *et al.,* (2016) and Cerdà *et al.,* (2016) showed that soil erosion was influenced greatly by anthropogenic activities in vineyards and barley, respectively. They observed highest soil loss and sediment discharge in the plantation of new vineyards and barley. Parras-Alcántara *et al.* (2016) demonstrated that olive grove management in Mediterranean soils could improve the soil qualities of olive orchards and it was more impressive for sandy soils decreasing the runoff and soil erosions. The rangelands in northern Iran is being degraded by anthropogenic activities mainly because of land use change and subsequently intensive rainfed/or irrigated farming (Khalilmoghadam *et al.,* 2009; Emadi *et al.,* 2009). The most common land use change in Babolrood watershed, northern Iran, is conversion of virgin rangelands into the orchard and rainfed farming land uses. To date, no study has been conducted to investigate the effects of land use change on USLE K-factor changes in northern Iran. Thus, the main objective of this study is to quantify changes of USLE K-factor and its soil driving factors by investigating the land use change from rangeland to rainfed farming and orchards in Babolrood watershed in northern Iran in 2015-16.

MATERIALS AND METHODS

Study area

The study area is located in Eastern Bandpay region, the south of Babol city, Mazandaran province, northern Iran (Fig. 1). The location of three studied land uses and sampling sites is illustrated in Fig. 1. The soil moisture regimes and temperature are xeric and thermic, respectively. The long-term means of annual precipitation and temperature were 799 mm/y and 17.1˚C, respectively. According to soil maps of the study area, all sampling sites in three land uses were located in the same soil type (classified as Typic Haploxerepts) and the other landscape characteristics including aspect, elevation (625 m a.s.l) and slope position were roughly identical. The assumption is that the changes in soil erodibility are caused only by land use change, and other soil-forming factors are the

Table 1: The main characteristics of the sampling sites in the three land uses

Soil type	Soil texture	Parent materials	Climate	Slope gradient (%)	Slope aspect
Typic Haploxerepts	Silty clay loam	Limestone	Hot-summer Mediterranean	3 to 5 %	North

same. Table 1 indicates the main characteristics of the sampling sites. A large portion of the watershed in the study area is covered with forests and rangelands in last decade. Fig. 2 shows overviews on the three land uses studied.

The sampling and analysis of soils

The composite soil samples were taken from two layers (0-20 and 20-40 cm) with four replications for the three land uses. In other words, in every land use, four soil composite samples were collected, as replication, from each depth. Totally, twenty-four undisturbed and disturbed soil composite samples were randomly selected for soil analysis. Disturbed soil samples were air-dried, sieved via a 2-mm mesh and finally analyzed for some soil physicochemical characteristics. The undisturbed samples were applied for bulk density and mean weight diameter (MWD) determination. The hydrometer method was applied to determine the soils' particle size

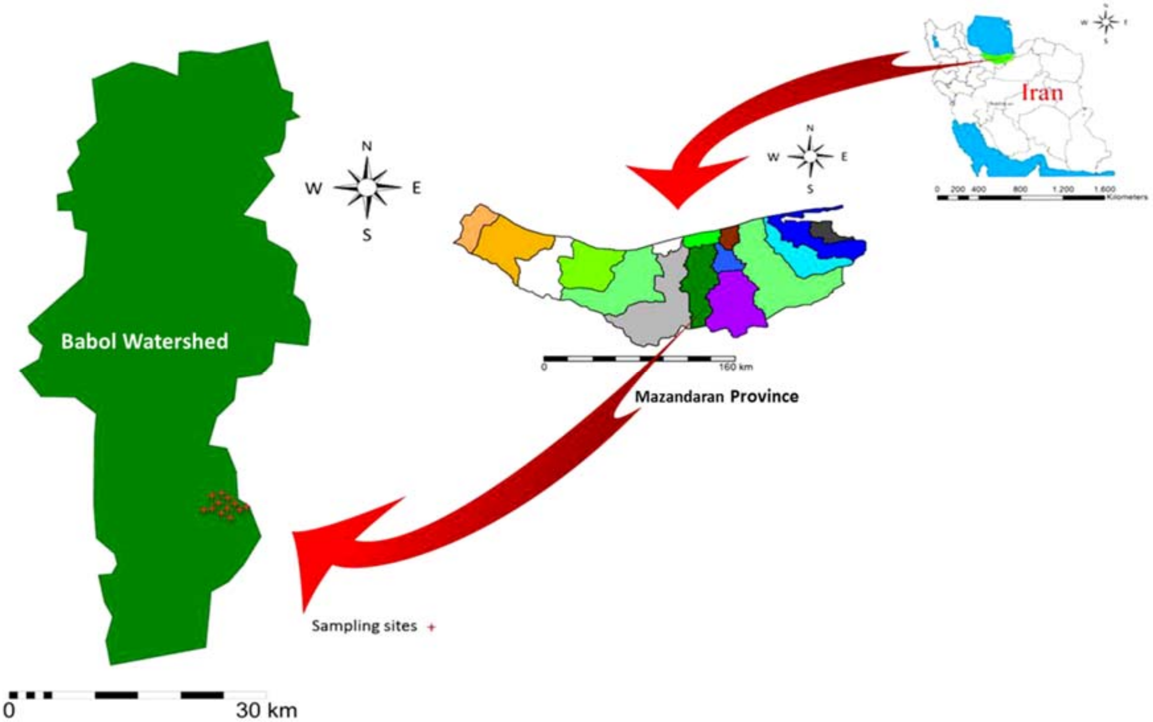

Fig. 1: Study area and sampling sites in different land uses in Mazandaran Province, northern Iran

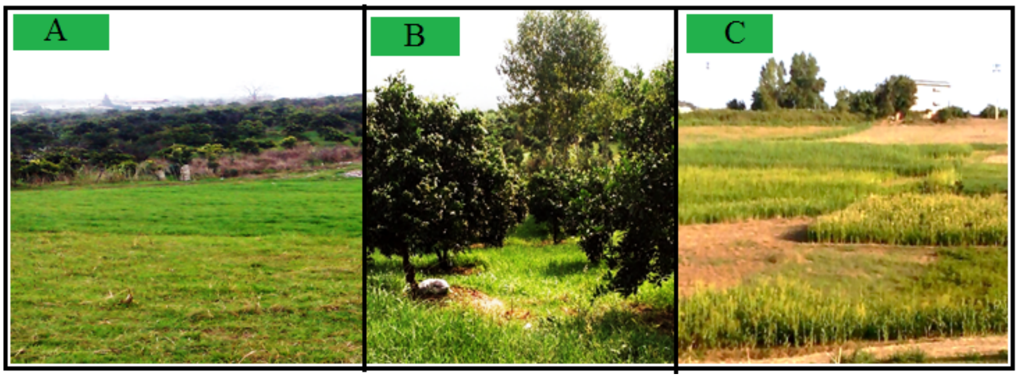

Fig. 2: Overviews of the three land uses including rangelands (A), orchards (B) and rainfed farming land (C)

distribution (Bouyoucos, 1962). The organic carbon (OC) of soil was measured using the Walkley-Black method (Walkley and Black, 1934) and multiplied by coefficient of 1.74 to measure OM of the soil. Moreover, wet sieving method was applied to identify the stability of soil aggregates quantified as MWD (Kemper and Rosenau, 1986). A nest of sieves with 2.0, 1.0, 0.5 and 0.25 mm diameters was used by vertically moving the sieve about 3 cm and for 50 times during 2.0 min. MWD is calculated using Eq. 1.

$$MWD = \sum_{i=1}^{n} \mathrm{Xi\ Wi} \tag{1}$$

Where, *Xi* represents mean diameter of each size fraction (2.0–1.0, 1.0–0.05, 0.5–0.25, and <0.25 mm); *Wi* represents proportion of total mass for each aggregate following subtracting the weight of sand/stone. The cylinder method was applied to find Bulk density in undisturbed samples. The particle density was measured through the method presented by Blake and Hartage (1986). Soil porosity is estimated by Eq. 2 (Danielson and Sutherland, 1986):

$$n = 1 - \left(\frac{P_b}{P_p}\right) \tag{2}$$

Where, *n, Pb* and *Pp* are values of soil porosity, bulk density (g/cm^3) and particle density (g/cm^3) respectively.

Determination of permeability by double ring method

The double rings method was applied to simulate soil permeability. Various infiltration equations for soil water infiltration were introduced using the experimental and observational data. The Kostiakov equation used is presented by Eq. 3 (Kostiakov, 1932):

$$I = c(t)^{\alpha} \tag{3}$$

Where, *t* stands for penetration time (at the start) in terms of minute, is infiltrated depth at the start of penetration in terms of cm, and are the empirical coefficients for different types of soil. Therefore, the infiltration was measured with the help of one-dimensional water flow into soil and double ring infiltrometer with 4 replications in three land uses (Fig. 3).

Estimation of USLE K-factor

K-factor can be calculated via the USLE which is frequently used to calculate soil loss based on other factors gained from the simulated or natural rainfall data (experimental) (Wischmeier and Smith, 1979). Soil erodibility is understood as a parameter which represents the raindrop and runoff effects on soil surface (Rodríguez *et al.,* 2006). Direct determination of erodibility using standard plots is the best way and eventually leads to a high accuracy of soil loss prediction. It is time and labor consuming, and usually not possible to set up a standard plot for each land use. Since filed measurements are expensive, difficult and sometimes hard to be conducted in the large scale, researchers have developed pedotransfer functions which indicate a relationship between certain soil property and readily available soil properties to predict soil erodibility (Panagos *et al.,* 2012; Ostovari *et al.,* 2015; Ostovari *et al.,* 2016) The most well-known approach is the USLE presented by Wischmeier and Smith, (1979) as in by Eq. 4.

$$\begin{aligned} K &= 2.8M^{1.14} \times 10^{-7} \times (12\text{-}\%OM) \\ &+ 4.3 \times 10^{-3} (S\text{-}2) + 3.3 \times 10^{-3}(P\text{-}3) \end{aligned} \tag{4}$$

Where, *K* denotes erodibility of soil (Mg h/MJ/mm), *M* is product of (100 – clay %) × (very fine sand (0.05–0.1 mm) + %silt), and *OM* refers to organic matter (%). Very fine sand was measured through wet sieving method with 270 mesh sieves (Kemper

Fig. 3: Permeability determination by double ring method in the first layer of rainfed farming

and Rosenau, 1986). The P coefficient was obtained through the measurement of infiltration rate by double rings method, and the S coefficient was determined using the shape and the size of soil aggregates (Vaezi *et al.,* 2008). In this study, the codes were assigned based on the measured MWD and field observation as described by Wischmeier and Smith (1979). In each land use, permeability was measured using double rings method at four replicates in the dry season to lower the effect on moisture on infiltration (Turner and Sumner, 1978).

Six classes are identified based on soil permeability classification (Wischmeier and Smith, 1979) in cm/h, as follows:

1. High to very high (>12.5)
2. Moderate to high (6.25 – 12.5)
3. Moderate (2 – 6.25)
4. Moderate to low (0.5- 2)
5. Low (0.125- 0.5)
6. Very low (<0.125)

Soil structure is divided into four classes according to the method suggested by Wischmeier and Smith (1979), as follows:

1. Very fine crumb and granular structure (<1mm)
2. Fine crumb and granular structure (1-2 mm)
3. Moderate crumb and granular structure (2-5 mm) and coarse structure (5-10 mm).
4. Massive structure (prismatic, columnar, and blocky).

The $CaCO_3$ content increases MWD, suggesting a decreased soil erodibility (Zhang *et al.,* 2008). Nevertheless, in most cases soil permeability and K-factor correlate significantly with the amount of very fine sand or silt and OM (Song *et al.,* 2005).

Statistical analysis

Factorial design was followed in completely randomized design (CRD) using SPSS software. All the analyses were done in four replications for each land use. The means were compared with the help of least significant difference (LSD) test at the $P<0.05$ significance level.

RESULTS AND DISCUSSION

Soil characteristics

The statistical results based on CRD indicated that all the parameters (clay, sand, silt+vfs, MWD, porosity, OM and k-factor) had significant differences in various land uses and depths. The physicochemical soils characteristics are illustrated in Table 2. Results indicated that soils in rainfed farming land use had significantly lower OM, porosity and aggregate stability than in other two land uses. The highest amounts of sand, clay and silt+vfs (very fine sand) were observed in rainfed farming, orchard and rangeland land uses, respectively. The highest amount of clay observed in both depths of rainfed farming land use compared with that in rangelands and orchards land used is probably attributed to the irrigation with muddy water as a usual water management (Table 2). The soils in the orchards had a considerably higher amount of ($p<0.05$) sand than the soils in the rangeland and rainfed farming lands in both depths (Table 2). The higher amount of sand observed in orchard land use can be attributed to the flooding irrigation of orchards by farmers. It can also be attributed to the selective leaching of the fine particles, which leads to the increase of sand portions in soil profile. In addition, incorporating the sand and manure during the plantation may be lead to the increase of sand in orchards. On average, the amount

Table 2: Comparison of means for some soil properties in various land uses and depths (0-20 and 20-40 cm)

Parameters	Rangelands		Orchards		Rainfed farming lands	
	0-20 cm	20-40 cm	0-20 cm	20-40 cm	0-20 cm	20-40 cm
Clay (%)	$25.45^{c}\pm2.49$	$38.8^{a}\pm1.63$	$33.46^{b}\pm1.88$	$37.91^{a}\pm2.26$	$38.8^{a}\pm1.63$	$38.8^{a}\pm1.63$
Sand (%)	$7.85^{d}\pm0.94$	$7.20^{d}\pm1.63$	$17.85^{a}\pm0.94$	$13.65^{b}\pm2.57$	$10.52^{c}\pm0.94$	$9.20^{cd}\pm1.63$
Silt+VFS^{1} (%)	$70.53^{a}\pm3.63$	$57.20^{b}\pm2.22$	$51.02^{d}\pm1.79$	$51.84^{cd}\pm1.22$	$53.59^{cd}\pm0.98$	$54.54^{bc}\pm1.96$
MWD^{2} (mm)	$1.41^{b}\pm0.12$	$1.41^{b}\pm0.05$	$2.13^{a}\pm0.58$	$2.42^{a}\pm0.27$	$0.79^{c}\pm0.16$	$1.69^{b}+0.05$
Porosity (%)	$55.33^{a}\pm0.01$	$51.99^{ab}\pm0.02$	$55.03^{a}\pm0.04$	$54.70^{a}\pm0.02$	$49.54^{b}\pm0.01$	$45.12^{c}\pm0.03$
OM^{3} (%)	$3.38^{b}\pm0.85$	$1.28^{c}\pm0.25$	$4.32^{a}\pm0.32$	$2.88^{b}\pm0.43$	$1.36^{c}\pm0.32$	$0.45^{d}\pm0.05$

[1]VFS: Very Fine Sand; [2]MWD: Mean weight diameter; [3]OM: Organic matter. Values presented in different letter (s) in each depth signify the meaningful statistical difference in LSD test at probability level of 0.05.

of sand in a 0-20-cm-layer of orchards soils was 56.02% and 41.06% more than that in the rangelands and rainfed farming lands, respectively. The amount of silt+vfs in the rangeland soils was significantly greater than in the orchards and rainfed farming soils. Rafi *et al.* (2014) stated that the percentage of silt in pasturelands was significantly increased as compared to agricultural land upon land use change. The lowest porosity in a 20-40-cm-layer of rainfed farming soil was 15.22% and 21.23% less than that in the rangelands and orchards, respectively. This is due to the cultivation and tillage operations which increase the soil compaction. Tillage in rainfed farming land use decreases the porosity in compensation of great and major pore linkages (Rasiah *et al.,* 2004). Decrease of porosity and collapse of pore duration at the soil surface can prevent permeability and therefore provide a favorable condition for formation of severe surface erosion and runoff. Lemenih *et al.,* (2005) noted that the main reasons for soil porosity reduction in the rainfed farming lands are the loss of soil OM and soil compaction. The highest rate of OM in a 0-20-cm-layer (4.32%) of orchards was more than that in the rangelands and rainfed farming lands, and this could be attributed to the common-place use of livestock manure in this land use type in northern Iran. Emadi *et al.,* (2009) reported that conversion of pasturelands into croplands in northern Iran led to the enrichment of organic matter in micro aggregate fraction (>0.25 mm) in the croplands. The intensive tillage in rainfed farming land use may result in the increase of aeration inducing the acceleration of organic carbon oxidations (Rezaei *et al.,* 2012). Most of the MWDs in the rangelands and especially orchards were between 2 and 4 mm, which is considered to be "very stable" as classified by Le Bissonnais (2005). These types of soils would not be eroded very easily nor would they be greatly affected by rainfall impact. However, in rainfed farming land use, the aggregate stability or MWD of wet aggregate size distribution is statistically lower than in the other two land uses (Table 2). Loss of OM with cultivation in rainfed farming land use is connected to the decrease of MWD, which leads to the degradation of macro-aggregates and makes soil more susceptible to erosion. According to Borselli *et al.* (2009), Wischmeier's nemograph (Wischmeier and Smith, 1979) cannot be applied to a silt content exceeding 70%. Since, in the studied watershed, the silt content ranges from 45.5% to 49.20%, the USLE nemograph is applicable. The higher MWD indicates that the soil is more stable in orchard. Soil aggregate stability, as a main trait of soil, controls soil erodibility (Cantón *et al.,* 2009). Emadi *et al.* (2008) and Rafi *et al.* (2014) investigated the significant reduction of aggregate stability in croplands as compared the pasture and forest soils. It was found that cultivation reduced the soil aggregate stability in rainfed farming lands because of decline in soil organic matter during agricultural practices. This was in agreement with the findings of Hairiah *et al.* (2006). Therefore, soil structure classes of rangelands, orchards and rainfed farming lands were assigned as 2, 3 and 4, respectively. Soil OM decomposition and soil compaction due to cultivation are the main reasons for soil structural damage in the rainfed farming land use.

Soil permeability

Table 3 represents the cumulative infiltration equations and the instant and average infiltration rates of three land uses estimated by the Kostiakov equation. As shown in Table 3, all the infiltration equations have a high coefficient of determination (R^2), indicating that they are well-qualified to be used for comparison. The infiltration rate in orchard land use was more than that in the other two land uses. As can be seen in Table

Table 3: Results of the double rings method in different land uses

Land use	The cumulative infiltration equation	The instant infiltration equation	The average infiltration equation	α and c coefficients
Rangelands	$I= 1.237t^{0.349}$ $R^2=0.97$	$I_{inst}=25.90\ t^{-0.651}$	$I_{ave}=74.22\ t^{-0.651}$	α =0.349, c=1.237
Orchards	$I=1.596t^{0.349}$ $R^2=0.98$	$I_{inst}=33.42\ t^{-0.651}$	$I_{ave}=95.76\ t^{-0.651}$	α =0.349, c=1.596
Rainfed farming lands	$I=1.117\ t^{0.351}$ $R^2=0.97$	$I_{inst}=23.52\ t^{-0.649}$	$I_{ave}=67.02\ t^{-0.649}$	α =0.351, c=1.117

3, the accumulation infiltration rates in the orchards are higher than those in the rangelands and rainfed farming land uses, showing that condition of the orchards soil is suitable for reducing the soil runoff and subsequently restricting the soil loss.

Fig. 4 shows the soil permeability in the three land uses. The soil permeability in the rainfed farming land use is significantly decreased in comparison with the rangelands and orchards land uses due to the long-term intensive agricultural operation and the sharp decline of organic matter and porosity and high bulk density. According to Wischmeier and Smith (1979), the soil permeability in the three studied land uses was in the class of moderate to low (0.5-2 cm/h). Therefore, the soil permeability class of 4 was assigned to rainfed farming lands, orchards and rangelands land uses with the soil permeability mean values of 0.94, 1.49 and 1.07 cm/h, respectively (Fig. 4). The lowest permeability in rainfed farming land use can be due to the high clay amount (smaller pore volume), low rate of OM and MDW. This is compatible with the findings of Larsson and Eliasson (2006) and Şeker (1999).

Soil erodibility factor

Soil erodibility is usually expressed experimentally as it is potentially varied in different regions due to the changes in soil properties. The difference between mean values of calculated USLE K-factor for the three land uses and the two layers has been presented in Table 4. The highest and lowest USLE K-factors were obtained in the rangeland (0.045 Mg h/MJ/mm) and orchard (0.030 Mg h/MJ/mm) land uses in depth of 0-20 cm, respectively. However, no meaningful difference was seen between the rangeland and rainfed farming land in the 0-20cm-layer in terms of the K-factor.

The main cause for the highest rate of erodibility within the rangeland (0.045 Mg h/MJ/mm) is the highest amount of silt+vfs in the 0-20-cm-layer. The silt+vfs lacks adhesion properties and if moisturized, becomes easily broken and transported, having an increased impact on soil erodibility (Huang and LO, 2015). The lowest erodibility rate in the orchards belonged to high rate of aggregate stability, organic matter and permeability. In depth of 20-40 cm, the highest rate of soil erodibility, which was significant,

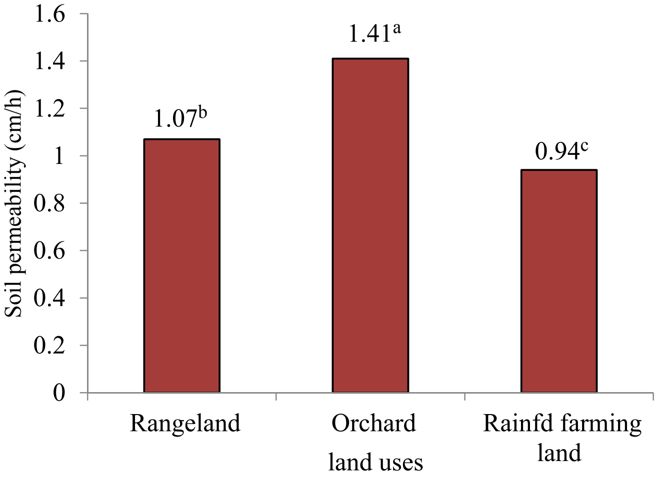

Fig. 4: Infiltration rate (cm/h) in the different land uses. Various letters indicate the meaningful difference (at probability=0.05)

Table 4: The calculated USLE k-factors in various land uses

Land use type	USLE K-factor (Mg h/MJ/mm) 0-20 (cm)	USLE K-factor (Mg h/MJ/mm) 20-40 (cm)
Rangelands	0.045^a±0.0013	0.036^b±0.0017
Orchards	0.030^d±0.0007	0.033^c±0.0022
Rainfed farming lands	0.043^a±0.0009	0.044^a±0.0006

Different letters indicate the significant statistical difference in LSD test at probability level of 0.05

Table 5: Correlation between soil properties and USLE K-factor

Variables	Clay	Silt	Sand	OM	MWD	PE	Si+VFs
Silt	-0.702**						
Sand	0.003	-0.666**					
OM	-0.639**	0.072	0.582**				
MWD	-0.012	-0.376*	0.556**	0.467*			
PE	-0.098	-0.446*	0.769**	0.746**	0.778**		
Si+VFs	-0.746**	0.996**	-0.615**	0.132	-0.326	-0.391*	
K-factor	0.376*	-0.106	-0.301	-0.686**	-0.621**	-0.777**	-0.150

OM: Organic matter; Si+VFS: Silt+very fine sand; PE: Permeability; MWD: Mean weight diameter.
**: significant at $p<0.01$; *: significant at $p<0.05$.

was observed in the rainfed farming land use. This can be because of the lowest rate of organic matter, porosity and permeability observed in the rainfed farming land in the 20-40-cm-layer. The decomposition of soil OM is increased by the physical disturbance caused by soil tillage, breaking down the macro-aggregates and exposing the C protected in their interiors to microbial decomposition (Celik 2005; Emadi *et al.,* 2009). This could probably correspond to the rangeland coverage that increases OM content, which ultimately leads to a lower K-factor (Tejada and Gonzalez, 2006). Meanwhile, intensive cultivation of agricultural lands in the rainfed farming land use with limited or no recycling of crop residues lowers the OM content, resulting in increment of K–factor (Duiker *et al.,* 2001; Huang and LO, 2015). In contrast, Cerdà *et al.,* (2009) stated that the erodibility in citrus orchards, developed over sloping lands in the Mediterranean soils, is significantly increased in comparison with fire-affected soils and even badland basins at watershed level. More recently, Cerdà *et al.,* (2017) recommended the application of straw mulches as an efficient soil management in Mediterranean rainfed farming land for reduction of runoff and soil loss. Aggregate stability, organic matter and permeability showed the greatest impact on erodibility in this catchment area. Celik (2005) showed that with decrease of the organic matter, wet aggregate stability, permeability and destruction of soil during changing from pasture and/or forest to agricultural lands, the soil erodibility is significantly increased. In the present study, soils' particle size distribution had considerable effects on soil erodibility, given that soil texture class is varied. It is more practical to measure the USLE K-factor relying on soil texture rather than a single particle size (Duiker *et al.,* 2001; Romero *et al.,* 2007; Martinez-Mena *et al.,* 2008). The analysis based on texture is a wiser way given that soil texture is responsible for the proportion of silt, sand, and clay existing in soil. Moreover, the removal of native vegetation accompanied with the decrease of soil qualities induced by land use change from rangeland to the rainfed farming, and finally made the soils more susceptible to soil erosion.

Relationships between USLE K-factor and soil characteristics

The relationship between the calculated USLE K-factor and soil characteristics is indicated in Table 5. Results indicated that soil erodibility in the study area is affected by MWD, permeability and OM. The K-factor has a negative and significant correlation with OM (r= -0.686), MWD (r= -0.621) and permeability (r= -0.777) at $p<0.01$. These are in accordance with the reports of Vaezi *et al.,* (2008), Shabani *et al.,* (2014) and Ostovari *et al.,* (2016). Charman and Murphy (2007) revealed that the high aggregate stability resulted in the high resistance to the detachment of particles by raindrops and runoff. Conversely, there was a negative correlation between permeability and K-factor, as reported by Emadi *et al.,* (2009). There is a positive and significant correlation between clay and USLE K-factor (r= 0.376 $p<0.05$). This is due to high adhesion of clay particles rather than other particles, as they don't easily separate from soil surface and contributes to the reduction of soil erodibility. However, no significant correlations were observed between USLE K-factor and silt, sand, and Si+VFs. Vaezi *et al.,* (2010) stated that the enhanced soil aggregation induced by soil organic matter can promisingly reduce soil erosion. The high rates of sand, organic matter, permeability and aggregate stability are the main driving factors controlling the USLE K-factor as previously reported by Evrendilek *et al.,* (2004) and Rodríguez *et al.,* (2006). These stem from formation of macro- and meso-pores that facilitate the water movement into the soils. Zhang *et al.,* (2004) concluded a significant negative correlation between the clay and USLE K-factor. Singh and Khera (2009) reported the descending order of erodibility index as farmland> bare land> rangeland> forest.

CONCLUSION

Comparison of soil erodibility (USLE K-factor) was conducted in three land uses in northern Iran. The obtained results indicated that the highest rate of soil erodibility belonged to the rangeland land use in the surface layer (0.045 Mg h/MJ/mm) as containing the highest amount of silt+vfs (70.53 %). Moreover, the soil erodibility in depths of 0-20 cm and 20-40 cm in orchard land use were 0.030 Mg h/MJ/mm and 0.033 Mg h/MJ/mm respectively. The soil MWD, permeability and OM was highest in orchard land use within land uses showing the more sustainability for runoff and sediment loadings. The results also indicated that organic matter, particle size distribution, permeability and aggregate stability had a great impact on soil erodibility. The findings suggest that soil erodibility has been heavily influenced by land use change. The orchard land use, converted from rangeland, did not show any increase in the intrinsic or semi-permanent soil erodibility based on the current type of soil management. Therefore, it can be introduced as a good alternative land use in sloping areas due to the enhancement of soil qualities, though more studies on environmental, social and economic aspects of this land use is needed. The results obtained in this study can be used/tested in other areas with the same soil type and landscape conditions.

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CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest regarding the publication of this manuscript.

ABBREVIATIONS

%	Percentage
°*C*	Centigrade degree
ANOVA	Analysis of variance
a.s.l	Above sea level
C	Carbon
C	Crop management
$CaCO_3$	Calcium carbonate
CO_2	Carbon dioxide
cm	Centimeter
cm/h	Centimeter per hour
cm^3	Cubic centimeter
CRD	Completely Randomized Design
g	Gram
g/cm^3	Gram per cubic centimeter
h	Hour
ha	Hectare
I	Infiltrated
K	Soil erodibility
L	Length
LSD	Least significant difference
m	Meter
Mg	Mega gram
Mg/ha/y	Mega gram per hectare per year
Mg h/MJ/mm	Mega gram hour per mega joule per millimeter
MJ	Mega Joule
mm	Millimeter
mm/y	Millimeter per year
MWD	Mean weight diameter
OC	Organic Carbon
OM	Organic Matter
P	erosion control practice
P	P- value
PE	Permeability
R	Soil erosivity
r	Correlation Coefficient
R^2	Coefficient of Determination
Si+VFs	Total Silt and Very fine sand
SPSS	Statistical package for social science
t	penetration time
USLE	Universal Soil Loss Equation
y	Year
vfs	Very fine sand

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AUTHOR (S) BIOSKETCHES

Taleshian Jeloudar, F., M.Sc., Department of Soil Sciences, Faculty of Crop Sciences, Sari Agricultural Sciences and Natural Resources University, Sari, Iran. Email: *fateretaleshian@yahoo.com*

Ghajar Sepanlou, M., Ph.D., Associate professor, Department of Soil Sciences, Faculty of Crop Sciences, Sari Agricultural Sciences and Natural Resources University, Sari, Iran. Email: *sepanlu@yahoo.com*

Emadi, S.M., Ph.D., Assistant Professor, Department of Soil Sciences, Faculty of Crop Sciences, Sari Agricultural Sciences and Natural Resources University, Sari, Iran. Email: *mostafaemadi@gmail.com*

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