

Deforestation effects on soil properties, runoff and erosion in northern Iran

Ataollah Kavian · Ali Azmoodeh · Karim Solaimani

Received: 8 December 2011 / Accepted: 21 January 2013 / Published online: 7 February 2013
© Saudi Society for Geosciences 2013

Abstract Improper cultivation practices are seriously degrading native forest ecosystems in northern Iran. Hence, the objectives of this study are to compare selected soil properties, runoff amount, erosion and also introducing equations to predict the runoff and soil erosion in three types of land use (forest, garden and cultivated). A simple portable rainfall simulator has been set in 90 random points to create experimental rainfall. Result showed that changes in natural forest led to a significant clay, organic carbon of soil, total N and antecedent soil moisture decrease and sand, pH and bulk density increasing. The rainfall runoff experiments indicate that runoff content of the natural forest soils was 35 % and respectively 38.45 % higher than the garden and cultivated land soils. This result could be related to the higher antecedent soil moisture in natural forest compared with the other land uses. According to the obtained results, garden soil erosion and cultivated land was 1.351 and respectively 1.587 times higher than the forest. The correlation matrix revealed that runoff content was positively correlated with antecedent soil moisture, bulk density and silt, and negatively with soil organic carbon, total N and sand. Also, soil organic carbon, total N, clay and sand showed negative correlation with soil erosion, while there is a positive correlation between erosion and silt, bulk density, pH and antecedent soil moisture. The results of multiple linear regression showed that runoff in forest, garden and cultivated land can be predicted with correlation coefficient of 0.637, 0.547 and 0.624, respectively. The correlation coefficients of 0.798, 0.628 and 0.560 in equations indicate their moderate potential in simulating soil erosion.

Keywords Land use change · Rainfall simulation, Soil quality · Organic matter

Introduction

Land use changes continually around the world by humans. Today, population increase and demand for agricultural products cause natural vegetation such as forests to be transformed to farmlands (Molina et al. 2008; Izquierdo and Ricardo Grau 2009). In the present time, unsubstantial land use changes are one of the most important problems in Iran because changing of dominant land use frequently was done without substantial schematization and consideration of environmental limitations. Land use changes in Iran have been more rapid in the past 50 years than at any time in Iran's history and are expected to continue or accelerate in the future (Emadodin 2008). In northern parts of Iran, Kelarestaghi and Jafarian Jeloudar (2011) expressed that area with forest land use decreased about 3.2 % and arable land increased about 36.9 % in transition 1967–2002.

Land use change, mainly through conversion of natural vegetation, may influence many natural phenomena and ecological processes (Yimer et al. 2007), leading to a remarkable change in soil properties (Marinari et al. 2006; Li et al. 2007), or cause increase bulk density (Bewketa and Stroosnijder 2003; Celik 2005) and can affect soil fertility. Runoff and soil erosion are natural processes that are greatly influenced by land use and management (Hacisalihoglu 2007), but these are accelerated by human activities such as industrial agriculture, urban sprawl, clearing vegetation or overgrazing. Martínez-Mena et al. (2008) described that the change from forest to cultivation led to a significant increase in total runoff and in mean sediment concentration. Girmay et al. (2009) presented that runoff coefficient, runoff volume and sediment yield were significantly higher in

A. Kavian (✉) · A. Azmoodeh · K. Solaimani
Sari Agricultural Sciences and Natural Resources University, Sari,
Mazandaran, Islamic Republic of Iran
e-mail: a.kavian@sanru.ac.ir

cultivated land than in the other land uses. The results of Fang et al. (2012) showed land use changes from cropland to forest and orchards caused significant decreasing trends in the runoff coefficients ($p < 0.01$) and sediment loads ($p < 0.01$). Runoff and soil erosion are one of the most important environmental problems which threaten soil and water sources. Land degradation caused by soil erosion not only involves the loss of fertile topsoil and reduction of soil productivity but also leads to sedimentation of reservoirs and increases suspended sediment concentrations in streams, decreases reservoirs and dam capacity (Abdinejad et al. 2011). For this reason, prevention of runoff and soil erosion is of paramount importance in the management and conservation of natural resources (Oyedele and Aina 1998). Many factors affect runoff and soil erosion such as rainfall characteristics, topography features, soil texture, permeability, antecedent soil moisture and soil management and tillage operations. Investigating the causes of runoff and soil erosion is difficult in natural conditions owing to the presence of other factors. The unpredictable, infrequent and random nature of natural rainfall makes the study of its effects on soils while rainfall is occurring difficult. Hence, application of simulation approaches is therefore necessary to simplify the prototype. The use of rainfall simulation can overcome some of these difficulties, and its low cost and easy operation allow for control over the water application rates and initial conditions (Sheridan et al. 2008).

Soil properties are one of the main parameters that affect runoff and soil erosion processes. Some researchers have also used the rainfall simulator to determine the effects of different variables on surface runoff and soil erosion. For example, Casermeiro et al. (2004) measured the amounts of runoff and erosion in 29 natural plots using a rainfall simulator. Their results show that plant cover is the main factor reducing surface runoff, movement of sediments and the supply of organic material. Marques et al. (2007) studied the erosive power of frequent light rainfalls. Field experiments of simulated rainfall were conducted over eight USLE plots with a slope of 10 %. Runoff and sediment amounts were negligible in covered plots, and this revealed the efficiency of vegetation cover. Molina et al. (2007) used a portable rainfall simulator to characterize the runoff response of 1-m² plots with different vegetation cover, soil type and lithology. They stated that the vegetation cover, soil organic matter and soil electrical conductivity are moderately correlated to runoff coefficients, and that bulk density is weakly correlated. Other variables such as rainfall intensity, soil texture, pH and antecedent moisture content are not significantly related to the runoff coefficients. Vahabi and Nikkami (2008) reported that efficient variables in soil erosion for 24.5-mm/h rainfall intensities are vegetation cover, clay content, sand content, antecedent soil moisture, silt content and slope, and at 32 mm/h, the efficient variables are vegetation cover, antecedent soil moisture, silt content, clay

content and slope. Zhang et al. (2011) used a rainfall simulator to investigate the effect of shrub *Caragana korshinskii* Kom. cover on runoff, sediment yield and nitrogen loss. The results indicated that in comparison to the bare soil plot, the vegetation-covered plots had about 20 % less runoff and 65 % less sediment. The concentration of N in both runoff water and the eroded sediment decreased with time and approached a steady value. Abdinejad et al. (2011) investigated the effects of soil texture and land slope sediment yield using a rainfall simulator and soil erosion plots. They mentioned that slope, clay and silt content had correlation coefficients of 0.689, 0.329 and -0.233 , respectively, at the 99 % confidence level with sediment yield.

Understanding the effects of land use changes on soil properties, runoff and soil erosion information have implications for devising land management strategies for identifying sustainable practices in each region. Therefore, this study was conducted to assess the impact of native forests conversion on some soil properties, runoff and soil erosion contents and to introduce equations for runoff prediction and soil erosion using a rainfall simulator in northern Iran. The results provide some guidance as the most suitable land uses for preventing soil degradation which, given forecasts concerning global warming, may be of considerable interest.

Material and methods

Study site

The case study of this article is Sari city located in Mazandaran province, in range of 36° 33'–36°35' latitude and 53° 10'–53°13' longitude in northern regions of Iran (Fig. 1). The altitudinal range of the case study is between 150 and 300 m above sea level with a mean annual precipitation of 600 mm. Most precipitations are during the winter and spring seasons

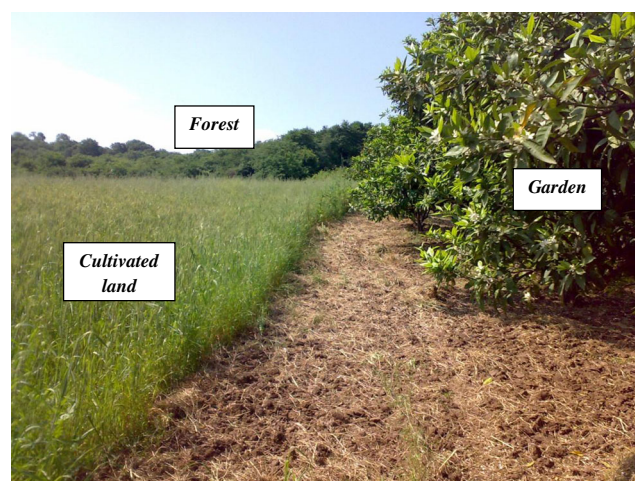


Fig. 1 Location of the study area and three adjacent land uses

(November–May), and means annual temperature ranges from 17.5 to 18 °C. Soil textures were loamy and clay-loam and classified as brown forest soils (Kavian et al. 2010). The soil depth is more than 1.5 m, and Ec is often less than 1 ds/m. Dominant land cover of the area are natural forest, garden and cultivated area. Concurrently, increasing population and the lack of new land for cultivation have forced people to transform former natural forests to garden and cultivated lands. Rainfall simulations were carried out to measure runoff and soil erosion from the three different land uses including: (1) natural forest, (2) cultivated area (wheat: *Triticum aestivum* L.) and (3) garden (orange garden). The cultivated area and garden have been converted from natural forest 20 years ago, and they were established at a height interval of 150 m from each other. Dominant tree species of these dense natural forests are *Carpinus betulus* and *Parrotia persica*. The passes during cultivation are considerable and stubbles which have been burned after harvesting in these regions.

Rainfall simulator set-up

A portable rainfall simulator was employed in this research which was developed at the Soil Conservation and Watershed Management Research Institute of Iran (Fig. 2). Raindrops fall from approximately 33–54 mm over the soil surface. The average diameter of the drops is 5.9 mm, and the average weight is 0.106 g. Kinetic energy of the rain is 4 Jm⁻²mm⁻¹. This type of rainfall simulator has been used by many research groups for similar investigations (Kamphorst 1987; Casermeiro et al. 2004; Jordan and Martinez-Zavala 2008; Kavian et al. 2010).

Plot characteristics, experimental design and measurements

The experimental plots were 30×30 cm with the same gradient of 15°. Three representative land use types were



Fig. 2 Rainfall simulation in cultivated area

selected for the experiment: forest land (30 points), cultivated (30 points) and garden (30 points). To ignore the effect of vegetation cover on runoff and soil erosion, we preferred to remove crop residue, root biomass and gravel more than 4 cm (Duiker et al. 2001; Feiznia et al. 2005). Also, in order to reduce microtopographical effects, the surface has been carefully smoothed (Zehetner and Miller 2006). Each rainfall event lasted for 15 min and 2 mm/min intensity. Therefore, rainfall intensity and duration, slope and other surface conditions of plot were similar. Before the rainfall simulation, soil samples were taken in or near the plot at a depth of 0 to 20 cm to characterize the physical and chemical properties, in particular soil texture, soil organic carbon, total N, antecedent soil moisture, bulk density and pH. The samples used for the laboratory analysis were first air-dried, lightly ground and screened through a 2-mm sieve. After each rainfall occurrence, runoff content is determined with a graduated cylinder, and the runoff samples were filtered, oven-dried at 105 °C, weighed to determine the suspended sediment concentration and finally soil erosion rate (Martinez-Mena et al. 2008).

Data analysis

One-way analysis of variance (ANOVA; SPSS 15) was used to compare the effects of land use change to selected physical and chemical properties, runoff and soil erosion. The DUNCAN procedure was conducted to compare soil properties mean at *p*<0.05. The correlation matrix and multi-variable regression method were used to determine the degree and type of correlation between variables. For this purpose, soil texture, soil organic carbon, antecedent soil moisture, bulk density and pH were considered as independent variables and runoff and soil erosion as the dependent variables. The root mean square error (RMSE) and the coefficient of efficiency (CE) as were proposed by Nash and Sutcliffe (1970) have been used for measured and predicted data. It is given by:

$$RMSE = \sqrt{\frac{\sum_{i=1}^n (Q_o - Q_e)^2}{n}} \tag{1}$$

$$CE = \frac{\sum_{i=1}^n (Q_o - Q)^2 - \sum_{i=1}^n (Q_o - Q_e)^2}{\sum_{i=1}^n (Q_o - Q)^2} \tag{2}$$

Where *Q*_o is the measured variable, *Q*_e is the predicted variable and *Q* is the arithmetic mean of *Q*_o for all events. Values of CE range from -∞ to 1. Low values of CE represent high deviations between measured and predicted values.

Results and discussion

Soil texture

Table 1 shows the soil properties of the experiment site. The result showed that land use affected the measured content of sand ($p < 0.001$) and clay contents ($p < 0.01$), but it did not have a significant interactive effect on silt contents ($p > 0.05$; Table 2). The mean sand contents were the lowest amount in the natural forest land (31 %) and the highest in the cultivated land (34.7 %), but there is no statistically significant difference between the garden and cultivated land at the 0.05 level (Fig. 3). Comparisons of mean differences among land uses revealed that clay contents under natural forest were significantly higher than the contents in the garden and cultivated land ($p < 0.01$), while no significant difference was observed between the garden and cultivated land (Fig. 3). The natural forest, garden and cultivated soils had similar contents of silt ($p > 0.05$; Table 2, Fig. 3). The general trend in soil texture after the natural forest converted into the garden and cultivated land showed an increase in the sand and a decrease in the clay contents. Under sparser vegetation covers, the clay fractions are likely to be lost in processes of selective erosion and migration down the soil profile. Also, loss of organic carbon in garden and cultivated soils is expected to break down the soil easily, and consequently, the finer particles are transported by erosion. This result is supported by findings of other researchers including Celik (2005) and Ayoubi et al. (2011).

Soil organic carbon and total nitrogen

The highest soil organic carbon (6.08 %) was calculated from the natural forest and the least soil organic carbon (3.17 %) was in the cultivated land. On average, SOC in the 0–20-cm-depth of the cultivated land soils were 48.71 and 23.8 % less than the forest and garden land soils, respectively (Table 1). The ANOVA indicated that conversion of the natural forest

Table 1 Selected physical and chemical properties (mean±SD) of adjacent natural forest, garden and cultivated land

Variable	Forest	Garden	Cultivated land
Sand (%)	31 (±2.097)	34.27 (±2.2)	34.7 (±2.9)
Silt (%)	34.3 (±2.58)	32.73 (±2.25)	33.3 (±2.18)
Clay (%)	34.7 (±2.23)	33 (±2.95)	32 (±2.4)
SOC (%)	6.08 (±0.337)	4.16 (±0.235)	3.17 (±0.406)
Total N (%)	3.06 (±0.11)	2.05 (±0.6)	1.57 (±0.2)
SM (%)	39.69 (±3.9)	25.8 (±2.82)	24.43 (±2.93)
BD (g/cm ³)	1.21 (±0.44)	1.3 (±0.457)	1.4 (±0.342)
pH	7.15 (±0.241)	7.41 (±0.258)	7.32 (±0.262)

SOC soil organic carbon, SM antecedent soil moisture, BD bulk density

Table 2 Results of the one-way analysis of variance of properties of the soils under the adjacent natural forest, garden and cultivated land ($p < 0.05$ indicates significant differences)

Parameter	Sum of square	Mean square	F	p
Sand	0.021	0.011	20.506	**
Silt	0.003	0.001	2.170	***
Clay	0.010	0.005	7.423	*
SOC	130.943	65.471	676.647	**
Total N	34.774	17.387	8.515	**
ASM	0.428	0.214	214.520	**
BD	0.517	0.258	144.647	**
pH	1.046	0.523	8.007	*

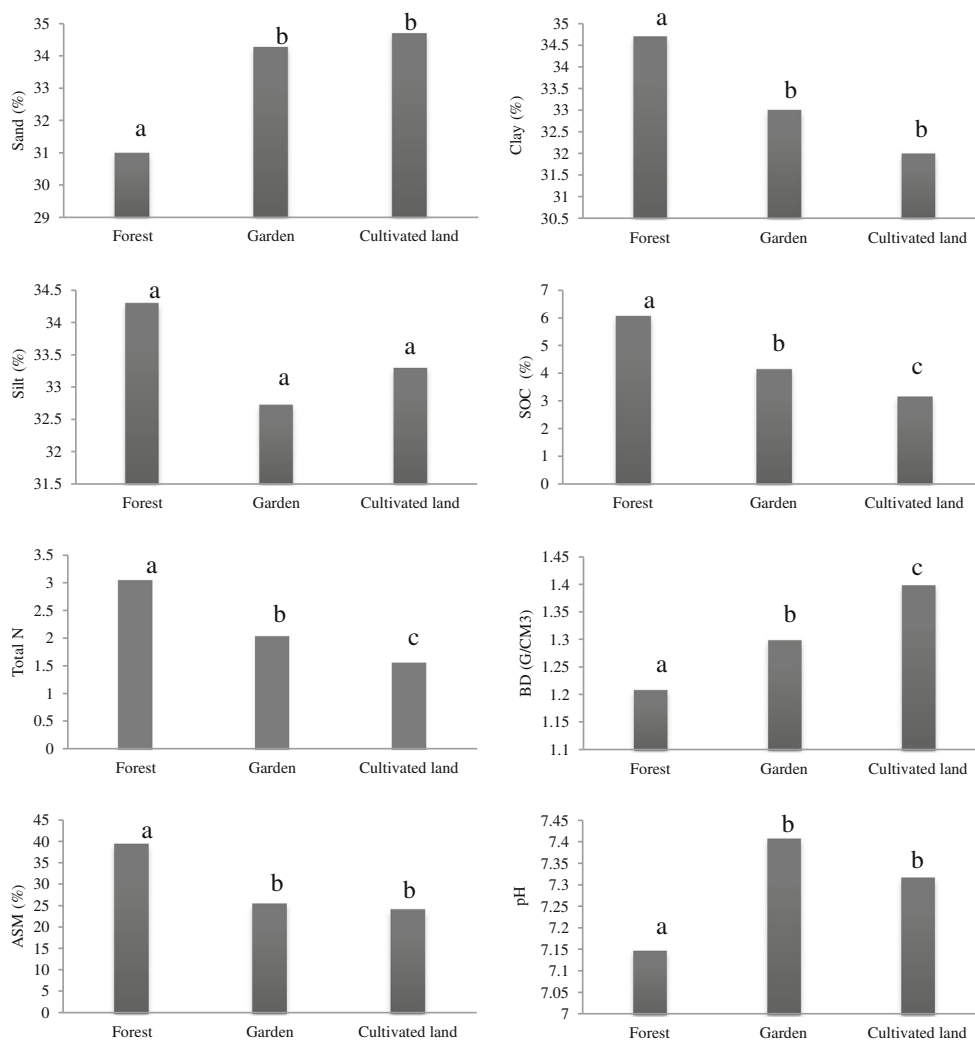
* $p < 0.01$; ** $p < 0.001$; *** $p > 0.05$, not significant

into garden and cultivated land resulted in significant reductions in SOC content ($p < 0.001$). The change of total nitrogen content followed a similar pattern as the organic carbon change ($p < 0.001$; Table 2). Related to total N of the natural forest soils, total N of the garden and cultivated soils decreased by 33 and 48.69 % than the natural forest, respectively (Table 1). The offered protection of the forest vegetation against erosion is certainly one of the key factors that explain these differences. The soil organic carbon and total N contents of the Cultivated and garden soil were significantly lower compared to native forest sites due to high rates of oxidation of soil organic matter and loss of organic matter by water erosion. The cultivation of native soils, which involves a reduced input of plant residues and a higher soil disturbance, causes a substantial reduction of SOC and total N levels. These impacts of cultivation caused by an increased decomposition rate and redistribution of SOC are a result of interactions of physical, chemical and biological soil processes. This is in agreement with results reported by other authors (Celik 2005; Yimer et al. 2007; Chibsa and Taa 2009).

Bulk density

The bulk density of the soils was lowest in areas under natural forest and highest in cultivated areas of wheat (Table 1). The ANOVA indicated a significant difference among the land use types ($p < 0.001$; Table 2). This difference might be ascribed to the compaction of the topsoil due to plowing applications and revolting of soil surface, it is compressed and so its exterior gravity will be increased. In addition, the higher SOC content of the natural forest as compared with the other types of land use is probably an important reason for the lower BD of the natural forest. Similar findings were reported by Bewketa and Stroosnijder (2003), Celik (2005) and Garcia-Orenes et al. (2005) that deforestation and subsequent tillage practices resulted in an increase in bulk density. However, there are also consequent

Fig. 3 The effect of land use change on the selected soil properties. Different letters varied significantly at the 0.05 probability level



studies such as that of Breuer et al. (2006) which did not find a significant change in bulk density caused by land use change.

Antecedent soil moisture

As expected, the antecedent soil moisture of soils under natural forests than the adjacent soils under garden and cultivated land was the highest (Table 1). The ANOVA analysis showed a significant difference among the land use types ($p < 0.001$; Table 2), but the garden and cultivated soils did not differ in soil moisture ($p > 0.05$; Fig. 3). Under forest soils, highest litter at the soil surface shades the soil, serves as a vapor barrier and suppresses evaporation against moisture losses from the soil (Adekalu et al. 2007; Mulumba and Lal 2008). Moreover, in garden and cultivated land, plowing changes the soil temperature, moisture and aeration, and it increases the decomposition rates of litter. Mc Dowell and Sharpley (2002) reported that when a soil is plowed and exposed to the air, it is accompanied with a decrease in soil moisture.

Soil pH

In this study, the variations in the soil pH under the different land use types were generally ranging from 7.15 to 7.41 in the surface of 0–20 cm. It was lowest in areas under natural forest and highest in areas of garden and cultivated (Table 1). The ANOVA established that there were significant differences between the soil pH depending on the land use change ($p < 0.01$; Table 2), but the garden and cultivated soils did not differ in soil pH ($p > 0.05$; Fig. 3). In general, cultivation caused an increase in soil pH to a low level. Conversion of

Table 3 Runoff content and soil erosion (mean±SD) of adjacent natural forest, garden and cultivated land

Variables	Forest	Garden	Cultivated land
Runoff (L/M ³)	16.39 (±1.23)	12.17(±1.25)	12.95 (±1.58)
Soil erosion (G/M ²)	11.47 (±3.16)	15.5 (±3.48)	18.21 (±5.34)

Table 4 Results of the one-way analysis of variance of runoff and soil erosion under the adjacent natural forest, garden and cultivated land

Parameter	Sum of square	Mean square	<i>F</i>	<i>p</i>
Runoff	301.828	150.914	80.593	*
Soil erosion	5.594	2.797	20.434	*

**p*<0.001

natural forest to garden and cultivated land seems to cause an increase in pH value probably due to management activities and agricultural practices in the area such as liming and the use of mineral fertilizers with subsequent alkaline reactions. For this reason, pH of soil garden and cultivated land is lower than forest land (Jiang et al. 2006; Geissen et al. 2009).

Runoff

Results of rainfall simulation indicated that change in land use significantly affected the amount of runoff content (*p*<0.001; Table 4). Runoff content at 20 cm depth was lower in the garden area (12.17±1.25 L/M²) and cultivated area (12.95±.58 L/M²) than in the natural forest (16.39±1.23 L/M²) area (Table 3). These results are discordant with those of Martinez-Mena et al. (2008), Girmay et al. (2009) and Fang et al. (2012) who found that the change from forest to another land use led to a significant increase in total runoff. The highest antecedent soil moisture in samples

from the natural forest compared with the other land uses is the main reason for the higher runoff in the natural forest. Higher initial soil water contents may cause reduction in soil pore space and consequently a reduction in permeability, and hence, the soil infiltrability is reduced under higher soil water contents. Many researchers (Castillo et al. 2003; Seeger et al. 2004; Martínez-Zavala et al. 2008; Liu et al. 2011) illustrated that antecedent soil moisture can be one of the most important factors controlling hydrological and consequently erosive processes. Antecedent soil moisture shows significant and high positive correlations with runoff content at natural forest, garden and cultivated area (*R*=0.735, *R*=0.660 and *R*=0.597, respectively; Table 5). Runoff content showed a negative correlation with soil organic matter and total N content in the three areas (Table 5). Soil organic matter increases soil porosity, thereby increasing infiltration and water-holding capacity of the soil and providing more water availability for plants. Casermeiro et al. (2004) and Molina et al. (2007) expressed that organic matter addition increased macroporosity, water infiltration rates and decreased runoff. However, high antecedent moisture in the natural forest soil can minimize the positive effect of SOC and total N in decreased runoff content in the natural forest. The bulk density produced a significant effect on the increase of runoff content that was consistent with a study carried out by Adekalu et al. (2006) (Table 5). This behaviour could be due to the soil bulk density increase and soil porosity reduction, thereby reducing soil infiltration, water and air storage capacities and increasing the surface runoff

Table 5 Coefficient of correlation matrix of runoff and soil erosion with independent variables

	Variable	Natural forest		Garden		Cultivated land	
		Pearson correlation	Sig	Pearson correlation	Sig	Pearson correlation	Sig
Runoff	Sand	-0.386*	0.035	-0.458*	0.011	-0.406*	0.026
	Silt	0.317****	0.088	0.289****	0.122	0.369*	0.045
	Clay	-0.319****	0.086	-0.249****	0.184	-0.149****	0.433
	SOC	-0.714***	0.000	-0.689***	0.000	-0.548**	0.002
	Total N	-0.686***	0.000	-0.680***	0.000	-0.530**	0.003
	ASM	0.735***	0.000	0.660***	0.000	0.597***	0.000
	BD	0.430*	0.018	0.548**	0.002	0.790***	0.000
	pH	0.209****	0.267	-0.122****	0.519	0.012****	0.951
Soil erosion	Sand	-0.323****	0.082	-0.301****	0.106	-0.674***	0.000
	Silt	0.417*	0.022	0.667***	0.000	0.294****	0.114
	Clay	-0.559**	0.001	-0.412*	0.024	-0.335****	0.070
	SOC	-0.763***	0.000	-0.722***	0.000	-0.662***	0.000
	Total N	-0.711***	0.000	-0.670***	0.000	-0.601**	0.002
	ASM	0.574**	0.001	0.612***	0.000	0.451*	0.012
	BD	0.273****	0.144	0.272****	0.145	0.383*	0.037
	pH	0.227****	0.228	0.364*	0.048	0.216****	0.253

p*<0.05; *p*<0.01; ****p*<0.001; *****p*>0.05, not significant

Table 6 Multiple regression equation, RMSE, CE and R^2 under the adjacent natural forest, garden and cultivated land

	Dependent variable	Multiple regression equation	RMSE	CE	R^2
Runoff	Forest	$2.084+0.013 \times SM-0.185 \times SOC$	0.067	0.615	0.637
	Garden	$1.966-0.294 \times SOC+0.014 \times SM$	0.074	0.548	0.547
	Cultivated	$-2.589+2.737 \times BD$	0.086	0.625	0.624
Soil erosion	Forest	$4.319-0.587 \times SOC-0.035 \times Clay+0.019 \times SM+0.022 \times Silt$	0.128	0.798	0.789
	Garden	$2.323-0.645 \times SOC+0.054 \times Silt$	0.187	0.626	0.628
	Cultivated	$6.173-0.087 \times Sand-0.480 \times SOC$	0.313	0.560	0.560

SOC soil organic carbon, SM antecedent soil moisture, BD bulk density

(Celik 2005; Adekalu et al. 2006). Sand content and surface runoff showed significant and negative correlation at the three land uses (Table 5); such findings were also reported by Adekalu et al. (2007), Jordan et al. (2008) and Vahabi and Mahdian. (2008). On the other hand, considering the negative correlation coefficient of sand content with runoff rate, with an increase in this variable, the runoff yield will decrease. The Pearson’s correlation results showed that significant positive relationships exist between silt and runoff in the cultivated land ($R=0.369$). In general, the silt content results in high soil susceptibility to surface sealing, crusting and caused an increase in runoff ratio (Mills and Fey 2004). In the present study, results revealed that clay content and pH show nonsignificant relationships with runoff content for all land use (Table 5).

Soil erosion

In this study, soil erosion was significantly affected ($p < 0.001$) by land use (Table 4). As the results show, soil erosion of the garden and cultivated soil was 1.351 and 1.587 times higher than the amount of the natural forest soil, respectively (Table 3). This result is consistent with the studies of Martinez-Mena et al. (2008), Girmay et al. (2009) and Fang et al. (2012). Based on the obtained results from the correlation matrix, both SOC and total N showed a strong correlation with soil erosion (Table 5), as observed by other authors (Tejada and Gonzalez 2006; Martinez-Zavala et al. 2008). These results indicate that by increasing of SOC and total N, soil erosion will be decreased. The organic matter increases aggregate stability by the enhancement of soil aggregation, inter-particle cohesion and soil

capability to withstand erosion. A significantly positive correlation was observed between the antecedent soil moisture and soil erosion (Table 5), indicating the importance of this variable for soil erosion. Antecedent soil moisture determines the magnitude of the slaking forces causing aggregate breakdown for the destruction of the soil surface structure and subsequent formation of a seal. Duiker et al. (2001) and Vahabi and Nikkami (2008) indicated that antecedent soil moisture is an efficient factor for increase of soil erosion. Table 5 shows that the mean soil erosion was correlated negatively with clay content and correlated positively with silt content in the natural forest and garden land. Sand content showed a negative correlation of -0.674 with soil erosion rates in the cultivated land. Sand particles have larger sizes so they are resistant to movement, and fine clay particles as a result of their stickiness are resistant to dis-jointing. Also, existence silt content cause a high soil susceptibility to surface sealing, crusting and increasing soil erosion. Zheng et al. (2004) and Korkanc et al. (2008) reported a negative correlation between clay content and soil erosion rate. Casermeiro et al. (2004) and Vahabi and Nikkami (2008) noted that an increase in the silt content causes an increase of the soil erosion rate. Similar negative relationships between sand content and soil erosion were found in researches of Vahabi and Nikkami (2008). The study also introduces a significant positive correlation between the BD and soil erosion ($R=0.383$) in the cultivated land, in accordance with other reports by Hartanto et al. (2003). This is contradictory to the results of Adekalu et al. (2006), who reported that compaction of soil results in high dry density, which will definitely reduce the rate of detachability and transportability of the soil particles. Pearson

Fig. 4 The effect of land use change on the runoff and soil erosion. Different letters varied significantly at the 0.05 probability level

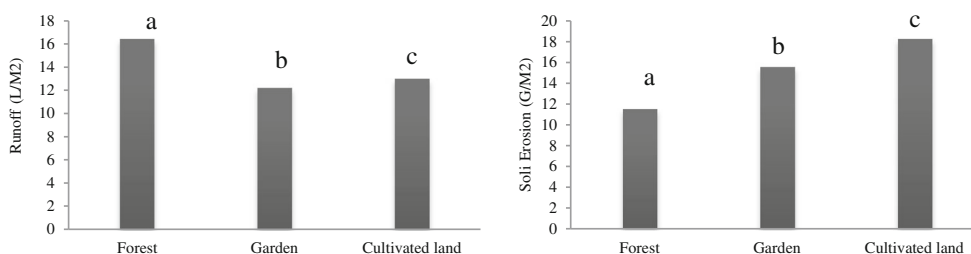
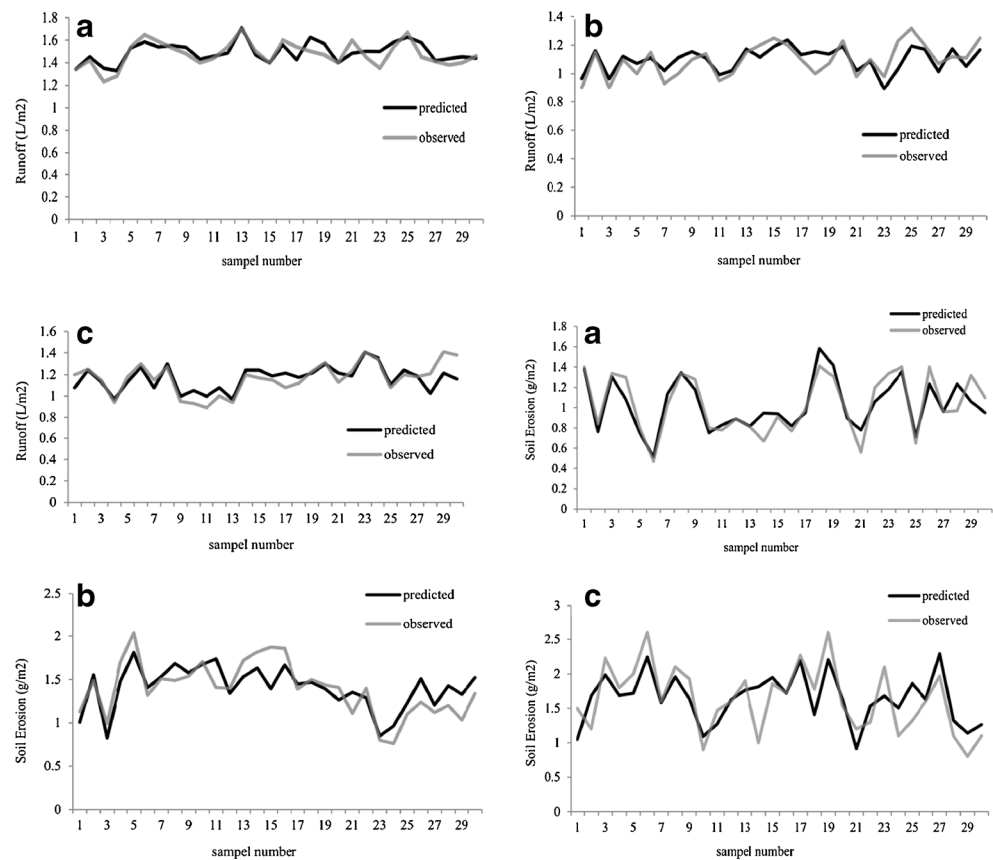


Fig. 5 Comparison between measured and predicted value: **a** forest, **b** garden, **c** cultivated land



correlation between pH and soil erosion was positive and weak (0.364) in the garden land (Table 5).

Multivariate linear regression

One of the fundamental goals in statistical investigations is to find a relationship between two or more variables. These relationships can be used to estimate the values of dependent variables for different conditions of existing independent variables, based on the established relationship. In this study, the stepwise method was the best model presented between independent variables and runoff and soil erosion. The results of multiple linear models showed that runoff can be predicted based on antecedent soil moisture, soil organic matter and bulk density (Table 6). According to Table 6, soil erosion can be predicted based on percentage antecedent soil moisture, soil organic matter, clay, silt and sand content. The results of MLR illustrated that runoff in forest, garden and cultivated land can be predicted with correlation coefficient of 0.637, 0.547 and 0.624, respectively. In the erosion model in forest, $R^2=0.798$ which indicates that 79.8 % of the observed dissipation in dependent variables can be justified by the four independent variables. The correlation coefficient between the measured and predicted soil erosion in garden and cultivated land was calculated as 0.628 and 0.560, respectively. The RMSE obtained for runoff content

in forest, garden and cultivated land was 0.067, 0.074 and 0.086, respectively. The values of the RMSE are 0.128 for forest, 0.187 for garden and 0.313 for cultivated land. The CE values of runoff models are 0.615, 0.548 and 0.625, for erosion model are 0.789, 0.626 and 0.560 for forest, garden and cultivated land, respectively. Considering the results obtained from the equation shown in Table 6 and the measured values of runoff rate and soil erosion, a graph between the measured and the predicted results is plotted (Figs. 4 and 5). It is observed from the presented figures that there is a little mismatch between the observed and estimated amount for all the three land uses.

Conclusion

We conclude that land use change leads to significant changes in soil properties, runoff content and soil erosion. Soils under three land use types in the north of Iran have been shown to differ markedly in their contents of sand, clay, SOC, total N, antecedent soil moisture, bulk density, pH, runoff content and soil erosion. The organic carbon and total nitrogen content of the natural forest were significantly higher than garden and cultivated land. These results confirm conclusions from several other experiments which have also shown a decrease in soil organic carbon and total

nitrogen after deforestation. The results showed that changes in natural forest led to a significant decrease in clay and antecedent soil moisture and significant increases in sand, pH and bulk density. Data from this study showed that runoff content was significantly higher in natural forest due to high antecedent soil moisture. Soil erosion content showed that the garden and cultivated soils were more susceptible to water erosion than the natural forest. The results of multiple linear regression showed runoff in forest, garden and cultivated land can be predicted with correlation coefficient of 0.637, 0.547 and 0.624, respectively. The correlation coefficients of 0.798, 0.628 and 0.560 in equations indicate their moderate potential in simulating soil erosion.

The conclusion of this research and similar studies can be used to enhance the determination of runoff and erosion rate of soils. In conclusion, when these systems are converted for agriculture without the use of proper practices of securing organic matter and soil stability, they are easily threatened. Therefore, conservation and good management after natural forest removal and reforestation can be continued in a way to provide a solution to the problems of soil degradation, nutrient depletion and to improve soil quality.

Acknowledgments This project was funded by Sari Agricultural Sciences and Natural Resources University (SANRU), Sari, Iran. We also thank Soil Conservation and Watershed Management Research Institute (SCWMRI) of Iran.

References

- Abdinejad P, Feiznia S, Pyrowan HR, Fayazi F, Tbakh Shabani A (2011) Assessing the effect of soil texture and slope on sediment yield of Marl units using a portable rainfall simulator. *J Am Sci* 7 (10):617–624
- Adekalu KO, Okunade DA, Osunbitan JA (2006) Compaction and mulching effects on soil loss and runoff from two southwestern Nigeria agricultural soils. *Geoderma* 137:226–230. doi:10.1016/j.geoderma.2006.08.012
- Adekalu KO, Olorunfemi IA, Osunbitan JA (2007) Grass mulching effect on infiltration, surface runoff and soil loss of three agricultural soils in Nigeria. *J Biortech* 98:912–917. doi:10.1016/j.biortech.2006.02.044
- Ayoubi S, Khormali F, Sahrawat KL, Rodrigues de Lima AC (2011) Assessing impacts of land use change on soil quality indicators in a loessial soil in Golestan Province. *Iran J Agr Sci Tech* 13:727–742
- Bewketa W, Stroosnijder L (2003) Effects of agro ecological land use succession on soil properties in Chemoga watershed, Blue Nile basin, Ethiopia. *Geoderma* 111:85–98
- Breuer L, Keller T, Huisman JA, Frede HG (2006) Impact of a conversion from cropland to grassland on C and N storage and related soil properties: analysis of a 60-year chronosequence. *Geoderma* 133:6–18. doi:10.1016/j.geoderma.2006.03.033
- Casmermeiro MA, Molina JA, Caravaca MTDL, Costa JH, Massanet MIH, Moreno PS (2004) Influence of scrubs on runoff and sediment loss in soils of Mediterranean climate. *Catena* 57:91–107. doi:10.1016/S0341-8162(03)00160-7
- Castillo VM, Gomez-Plaza A, Martinez-Mena M (2003) The role of antecedent soil water content in the runoff response of semiarid catchments: a simulation approach. *J Hydrol* 284:114–130. doi:10.1016/S0022-1694(03)00264-6
- Celik I (2005) Land-use effects on organic matter and physical properties of soil in a southern Mediterranean highland of Turkey. *Soil Till Res* 83:270–277. doi:10.1016/j.still.2004.08.001
- Chibsa T, Taa A (2009) Assessment of soil organic matter under four land use systems in Bale Highlands, Southeast Ethiopia. A. Soil organic matter contents in four land use systems: forestland, grassland, fallow land and cultivated land. *World Appl Sci J* 6 (9):1231–1246
- Duiker SW, Flanagan DC, Lal R (2001) Erodibility and infiltration characteristics of five major soils of southwest Spain. *Catena* 45 (2):103–121
- Emadodin I (2008) Human-induced soil degradation in Iran. Ecosystem services workshop, Salzau Castle, 13–15 May, Kiel, Northern Germany.
- Fang NF, Shi ZH, Li L, Guo ZL, Liu QJ, Ai L (2012) The effects of rainfall regimes and land use changes on runoff and soil loss in a small mountainous watershed. *Catena* 99:1–8. doi:10.1016/j.catena.2012.07.004
- Feiznia S, Ghaoumian J, Khadjeh M (2005) The study of the effect of physical, chemical, and climate factors on surface erosion sediment yield of loess soils (case study in Golestan province). *Research and constituent* 66:14–24
- Garcia-Orenes F, Guerrero C, Mataix-Solera J, Navarro-Pedreno J, Gomez I, Mataix-Beneyto J (2005) Factors controlling the aggregate stability and bulk density in two different degraded soils amended with biosolids. *Soil Till Res* 82:65–76. doi:10.1016/j.still.2004.06.004
- Geissen V, Sánchez-Hernández R, Kampichler C, Ramos-Reyes R, Sepulveda-Lozada A, Ochoa-Goana S, de Jong BHI, Huerta-Lwanga E, Hernández-Daumas S (2009) Effects of land-use change on some properties of tropical soils—an example from Southeast Mexico. *Geoderma* 151:87–97. doi:10.1016/j.geoderma.2009.03.011
- Girmay G, Sing BR, Nyssen J, Borrosen T (2009) Runoff and sediment-associated nutrient losses under different land uses in Tigray, Northern Ethiopia. *J Hydrol* 376:70–80. doi:10.1016/j.jhydrol.2009.07.066
- Hacisalihoglu S (2007) Determination of soil erosion in a steep hill slope with different land-use types: a case study in Mertesdorf (Ruwertal Germany). *J Environ Biol* 28:433–438
- Hartanto H, Prabhu R, Widayat ASE, Asdak C (2003) Factors affecting runoff and soil erosion: plot-level soil loss monitoring for assessing sustainability of forest management. *Forest ecol manag* 180:361–374
- Izquierdo AE, Ricardo Grau H (2009) Agriculture adjustment, land-use transition and protected areas in Northwestern Argentina. *J Environ Manage* 90:858–865. doi:10.1016/j.jenvman.2008.02.013
- Jiang YJ, Yuan DX, Zhang C, Kuang MS, Wang JL, Xie SY, Li LL, Zhang G, He RS (2006) Impact of land-use change on soil properties in a typical karst agricultural region of southwest China: a case study of Xiaojiang watershed. *Yunnan Environ Geol* 50:911–918
- Jordan A, Martinez-Zavala L (2008) Soil loss and runoff rates on unpaved forest roads in southern Spain after simulated rainfall. *Forest Ecol Manag* 255:913–919. doi:10.1016/j.foreco.2007.10.002
- Jordan A, Martinez-Zavala L, Bellinfante N (2008) Heterogeneity in soil hydrological response from different land cover types in southern Spain. *Catena* 74:137–143. doi:10.1016/j.catena.2008.03.015
- Kamphorst A (1987) A small rainfall simulator for the determination of soil erodibility. *Netherlands J Agr Sci* 35:407–415
- Kavian A, Azmodeh A, Soleimani K, Vhabzade GH (2010) Effect of soil properties on runoff and soil erosion. *J Ranges Watershed Manag* 63(1):1–15

- Kelarestaghi A, Jafarian Jeloudar Z (2011) Land use/cover change and driving force analyses in parts of northern Iran using RS and GIS techniques. *Arab J Geosci* 4:401–411. doi:10.1007/s12517-009-0078-5
- Korkanc SY, Ozyuvaci N, Hizal A (2008) Impacts of land use conversion on soil properties and soil erodibility. *J Environ Biol* 29(3):363–370
- Li XG, Li FM, Zed R, Zhan ZY, Singh B (2007) Soil physical properties and their relations to organic carbon pools as affected by land use in an alpine pastureland. *Geoderma* 15:98–105. doi:10.1016/j.geoderma.2007.01.006
- Liu H, Lei TW, Zhao J, Yuan CP, Fan YT, Qua LQ (2011) Effects of rainfall intensity and antecedent soil water content on soil infiltrability under rainfall conditions using the run off-on-out method. *J Hydrol* 396:24–32. doi:10.1016/j.jhydrol.2010.10.028
- Marinari S, Mancinelli R, Campiglia E, Grego S (2006) Chemical and biological indicators of soil quality in organic and conventional farming systems in Central Italy. *Ecol Indicators* 6:701–711
- Marques AMJ, Bienes R, Jimenez L, Perez-Rodríguez R (2007) Effect of vegetal cover on runoff and soil erosion under light intensity events. Rainfall simulation over USLE plots. *Sci Total Environ* 378(1–2):161–165. doi:10.1016/j.scitotenv.2007.01.043
- Martinez-Mena M, Lopez J, Almagro M, Boix-Fayos V, Albaladejo J (2008) Effect of water erosion and cultivation on the soil carbon stock in a semiarid area of south-east Spain. *Soil Till Res* 99:119–129. doi:10.1016/j.still.2008.01.009
- Martínez-Zavala L, Jordán-L A, Bellinfante N (2008) Seasonal variability of runoff and soil loss on forest road back slopes under simulated rainfall. *Catena* 74:73–79. doi:10.1016/j.catena.2008.03.006
- Mc Dowell RW, Sharpley AN (2002) Phosphorus transport in overland flow in response to position of manure application. *J Environ Qual* 31(1):217–227
- Mills AJ, Fey MV (2004) Effects of vegetation cover on the tendency of soil to crust in South Africa. *Soil Use Manage* 20:308–317. doi:10.1079/SUM2004262
- Molina A, Govers G, Poesen J, Van Hemelryck H, De Bièvre B, Vanacker V (2008) Environmental factors controlling spatial variation in sediment yield in a central Andean mountain area. *Geomorphology* 98:176–186. doi:10.1016/j.geomorph.2006.12.025
- Molina A, Govers G, Vanacker V, Poesen J, Zeelmaekers E, Cisneros F (2007) Runoff generation in a degraded Andean ecosystem: interaction of vegetation cover and land use. *Catena* 71:357–370. doi:10.1016/j.catena.2007.04.002
- Mulumba L, Lal R (2008) Mulching effects on selected soil physical properties. *Soil Till Res* 98:106–111. doi:10.1016/j.still.2007.10.011
- Nash JE, Sutcliffe JV (1970) River flow forecasting through conceptual models part I - A discussion of principles. *J Hydrol* 10(3):282–290
- Oyedele DJ, Aina PO (1998) A study of soil factors in relation to erosion and yield of maize on a Nigerian soil. *Soil Till Res* 48:115–125
- Seeger M, Errea MP, Begueria S (2004) Catchment soil moisture and rainfall characteristics as determinant factors for discharge/suspended sediment hysteretic loops in a small headwater catchment in the Spanish pyrenees. *J Hydrol* 288:299–311. doi:10.1016/j.jhydrol.2003.10.012
- Sheridan G, Noske P, Lane P, Sherwin C (2008) Using rainfall simulation and site measurements to predict annual inter rill erodibility and phosphorus generation rates from unsealed forest roads: validation against in-situ erosion measurements. *Catena* 73:49–62. doi:10.1016/j.catena.2007.08.006
- Tejada M, Gonzalez JL (2006) The relationships between erodibility and erosion in a soil treated with two organic amendments. *Soil Till Res* 91:186–198. doi:10.1016/j.still.2005.12.003
- Vahabi J, Mahdian MH (2008) Rainfall simulation for the study of the effects of efficient factors on runoff rate. *Soil Conserv Watershed Manag Res Cent* 95:1439–1445
- Vahabi J, Nikkani D (2008) Assessing dominant factors affecting soil erosion using a portable rainfall simulator. *International J Sediment Res* 23:375–385
- Yimer F, Ledin S, Abdelkadir A (2007) Changes in soil organic carbon and total nitrogen contents in three adjacent land use types in the Bale Mountains, south-eastern highlands of Ethiopia. *Forest Ecol Manage* 242:337–342. doi:10.1016/j.foreco.2007.01.087
- Zehetner F, Miller WP (2006) Erodibility and runoff-infiltration characteristics of volcanic ash soils along an altitudinal climosequence in the Ecuadorian Andes. *Catena* 65:201–213. doi:10.1016/j.catena.2005.10.003
- Zhang GH, Liu GB, Gl W (2011) Effects of *Caragana korshinskii* Kom. cover on runoff, sediment yield and nitrogen loss. *Int J Sediment Res* 25(3):245–257
- Zheng FL, Merrill SD, Huang CH, Tanaka DL, Darboux F, Liebig MA, Halvorson AA (2004) Runoff, soil erosion and erodibility of conservation reserve program land under crop and hay production. *Soil Sci Soc Am J* 68(4):1322–1341