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Effect of sediments on formation and evolution of soils in Benaft area of Kasilian basin in Mazandaran

Seyede Samereh Pirzadeh[1], Abbas Ahmadi[2,*], Ebrahim Pazira[3], Ali Mohammadi Torkashv[4], and Abolfazl Moeini[5]

[1]Ph.D. Candidate, Department of Soil Science, Science and Research Branch, Islamic Azad University, Tehran, Iran

[2]Associate professor, Department of Soil Science, University of Tabriz, Tabriz, Iran

[3]Professor, Department of Soil Science, Science and Research Branch, Islamic Azad University, Tehran, Iran

[4]Associate Professor, Department of Soil Science, Science and Research Branch, Islamic Azad University, Tehran, Iran

[5]Assistant Professor, Department of Forests, Range and Watershed Management, Science and Research Branch, Islamic Azad University, Tehran, Iran

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Abstract

The different morphological, physical, and geochemical properties of soils reflect the difference in the chemical composition of the parent materials. Due to the importance of the effect of soil properties on many management programs, the present study aimed to investigate the factors affecting the evolution of different soils in some lands of Kasilian basin in Mazandaran, Iran. For this purpose, seven profiles were excavated from different profiles and sections under study as the control profiles in forest, rangeland, and agricultural land uses of the region with different geological formations. The samples were transferred to the laboratory and the physical and chemical properties were determined. The soils were then classified according to the 2014 keys. The evolution levels of different soils and the reasons for this difference were compared. The study results showed that the climate is almost the same in the region and its effect on the soil is also similar. However, what even alleviates the impact of climate and forms diverse soils in the region is the diversity of geological formations, slope, and relief. The role of humans in cutting down forest trees and occupying lands around residential areas and changing the land use is among the factors affects the situation of soils in the current conditions. The comparison of soils in the

* Corresponding Author's Email: a_ahmadi@tabrizu.ac.ir

occupied lands with those in the forest lands shows how much the soil degradation has progressed, and the presence of entisols and inceptisols in the vicinity of mollisols shows the soil change in similar natural conditions due to the land use change. The results can be a model of soil change and land use in Hyrcanian forests. It is recommended to provide conditions to stop deforestation in the area and allow the natural growth of forest trees in the abandoned lands.

Keywords: Soil evolution; Land-use change; Hyrcanian forests; Kasilian; Soil quality.

1. Introduction

Soil is a valuable natural resource on the planet whose degree of evolution affects the characteristics and applications in agricultural activities and natural resources (Schaetzl and Anderson, 2005). It is also considered as a collection of living organisms and non-renewable natural resources (Izquierdo and Ricardo Grau, 2009). Climate, relief, vegetation, parent materials, and time are among the factors effective in soil formation, and various characteristics such as porosity, apparent and actual bulk density, amount of clay and carbonates are also affected by the soil-forming factors (Baybordi, 2000; Gholami Tabasi *et al*., 2013). By studying the forest soils of Khairudkenar near Nowshahr, Aliolad *et al*. (2010) stated that climate, relief and vegetation play an important role among other soil-forming factors, and the decalcification, humification, mud formation, accumulation, and clay movement were identified as the important processes in the evolution of the studied soils. Inadequate land use change leads to the decreased area of rangelands and forests, soil and groundwater pollution, reduced soil quality, and permanent destruction of land fertility (Izquierdo and Ricardo, 2009).

Forest soils have always been considered due to the high content of organic matter and suitable structure, but the changes in their management and use and the tillage practices generally have a major influence on the amount of organic matter and other physical and chemical properties of the soil (Hagedorn *et al*., 2001; Stoate *et al*., 2001; Dawson and Smith, 2007). Organic matter has a major effect on the increased crop production and also has a direct effect on the physical and chemical properties of the soil. The organic matter of soil prevents aggregate collapse (Emadi *et al*., 2009), reduces erodibility (Kay, 2000; Celik, 2005), increases water retention capacity (Rumpel *et al*., 2009), increases soil permeability (Arnau-Rosalen *et al*., 2008), improves soil structure, and prevents formation of crust (Castro Filho *et al*., 2002) and many other factors, eventually resulting in the reduced soil erosion (Yousefifard *et al*., 2007; Bhupinderpal *et al*., 2004). Therefore, the degradation of physical soil properties occurs following the reduction of organic matter in agricultural lands.

The different morphological, physical, and geochemical properties of soils reflect the differences in the chemical composition of the parent material (Irmak *et al*., 2007). Sheklabadi (2000) stated that the lowest amount of lime is present in the soils from igneous formations and the maximum amount in the soils from calcareous and dolomitic formations. In arid areas, marls are considered as the parent materials with high sensitivity to erosion and the source of sediment production. As a result, the evolution of horizons and soil depth in these formations are low. The distinctive feature of the marl lands of the third period is the presence of large amounts of salt, gypsum and lime. Gypsum is one of the most common sulfate minerals that is the main component of gypsum soils in geological sediments (Owliaie *et al*., 2006). Also, in a study, Boyadgiev (1974) stated that in the region of Iraq, the soils with more than 15% gypsum have unstable structure and the soils with 10-35% gypsum are subjected to settling and unsuitable for the construction of irrigation channels. Owliaie *et al*. (2006) stated that in the arid and semi-arid regions of Iran, the physical and chemical properties of soils are completely subject to the calcareous parent rock and create lime-rich soils. Organic carbon, amount and type of clay, color, presence or absence of calcium carbonate, higher solubility of salts, and leaching depth of soils are closely related to climate (Birkeland, 1999). Considering the importance of soil and the effect of its characteristics on many management programs, this study aims to investigate the causes of different soil formation in the Kasilian region of Mazandaran province. Similar conditions in this area can be found as scattered in many other parts of the Hyrcanian forest by taking a quick look at satellite images. It is expected that the results of this study will be significant for forest areas and forest dwellers due to the repeatability in other places.

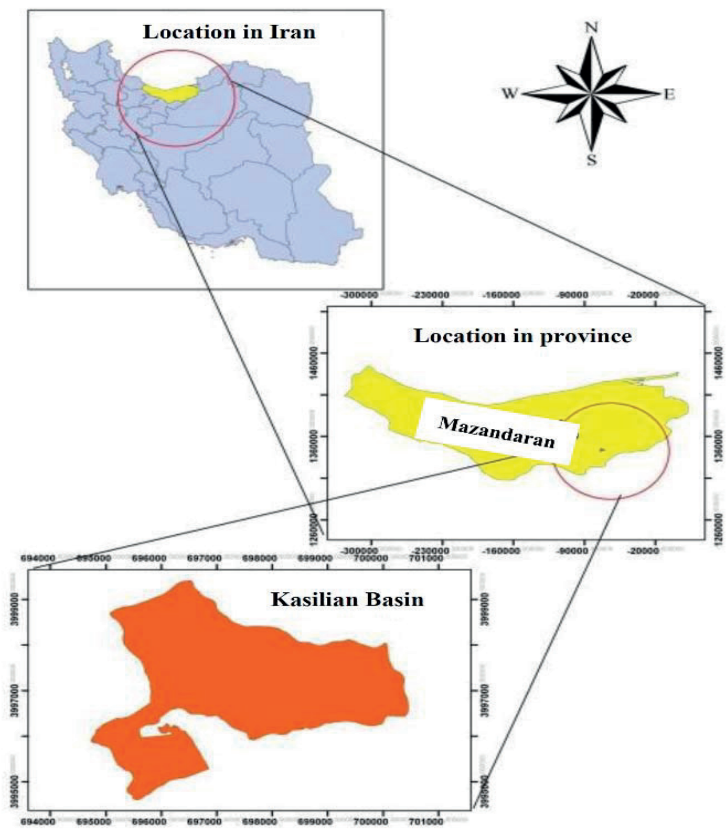

Figure 1. Location of study area

Table 1. Details of rain gauge stations in study area

Station	Coordinate		Rainfall (mm)			Elevation
	X	Y	Min	Mean	Max	
	699549	3997160	481	850	1378.5	1500
	697205	3996799	264	518.1	899.5	1250

2. Materials and methods

2.1. Study area

The study area of Kasilian is part of Dudangeh region located in the southern heights of Sari, where the elevation varies from about 1100 m to more than 1600 m above sea level. It covers an area of about 6792 hectares and includes various physiographic and geological units. This relatively small area has a great diversity in terms of soil and geological formations. Figure 1 shows the study area. The Benaft area in Kasilian basin can be a pattern of land use change in Hyrcanian forests. The satellite images show that this form of land use change has been repeated in different areas and forested villages.

2.1.1Climate

The study area does not have climatological or synoptic stations and there are two rain gauge stations in the area, Velikchal and Nodkola, and the data of the stations are summarized in Table 1 (Meteorological Organization of Iran, 2020). The average temperature in the region is about 11.5 °C. In general, the climatic classification of the region is cold humid by the Emberger method and according to the de Martonne method, the eastern part is cold very humid and the humid and the western part cold is cold humid.

2.1.2 Geology

The study area has geological diversity and the identified formations are:

1) Shemshak formation (TR3JS)
This formation consists of two main parts, but the main components are shale, sandstone, siltstone, claystone, and quartzite sandstone. This formation is low in permeability.
Profiles 3 and 4 were excavated and studied in this formation. The coefficient of sensitivity to the PSIAC erosion in this formation is 5.
2) Delichai formation (jd)
This formation is also composed of marl, calcareous marl and light green ammonite-bearing marl limestone and has often a low permeability. Profile 4 is located in this formation. The coefficient of sensitivity to the PSIAC erosion in this formation is 6.
3) Lar formation (l1J)
This formation is permeable and consists of ammonite-bearing chert limestone. Profile 1 is located in this formation and the coefficient of sensitivity to the PSIAC erosion in this formation is 3. Shemshak formation is related to the Triassic period and Lar and Delichai formations are related to the Jurassic period.
4) Fourth-period deposits (Q)
These deposits include alluvial fans and Quaternary alluvial terraces. Profiles 5, 6 and 7 were studied in this drilling unit. The coefficient of sensitivity to the PSIAC erosion .in this formation is 9
In PSIAC method, the higher the coefficient, the more erosionability the formation will be. Therefore, Quaternary alluvial terraces have the highest susceptibility to erosion among the

formations of the region. Figure 2 shows the geology of the study area. According to Figure 2, the highest area is related to the Quaternary Formation, which has the highest sensitivity to erosion.

2.1.3 Geomorphology

Two opposite geomorphological units were identified in the area, which include hills and sedimentary and alluvial sediments. Figure 3 shows the geomorphology of the area. The symbols used in the map are as follows.

A.CRH = agricultural lands

HRC.F = hills with regular slopes and forest cover

HRC.R = hills with regular slopes and rangeland cover

B = residential areas

To investigate the effect of land use on the physical and chemical properties of soil, the analysis of variance test was performed.

2.2. Data

The scope of the watershed was delineated based on the satellite images and topographic maps. The area was then surveyed and profiled

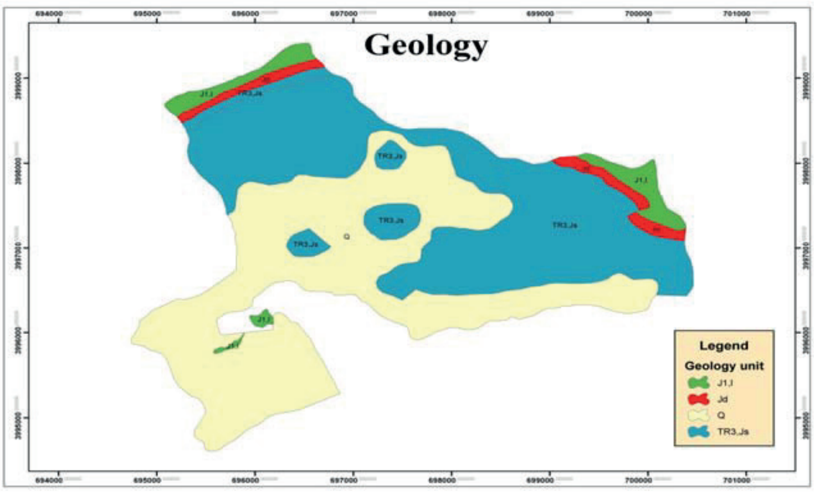

Figure 2. Geology of region

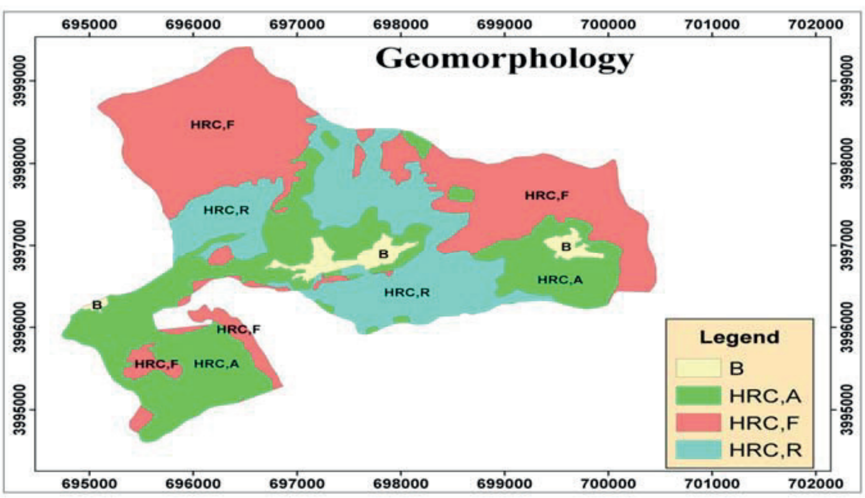

Figure 3. Geomorphology of region

followed by selecting and studying in detail a number of soil sections where the soil variations were relatively large across an acceptably large extent. Using geological maps, the extents of different formations were identified, and the land components were determined. Considering the available geological and geomorphological data (Prepared by the Geological Organization of Iran) and interpretation of the satellite images (Landsat 8 Date 02.05.2020) combined with terrestrial observations and profile descriptions of the profiles and the land component sections, different land components were distinguished. The land components were considered as relatively homogeneous work units, and the pedological studies were focused on these units. The units were relatively identical in terms of the soil, physiography, climate, and the parent materials, with an attempt made to take into consideration the relation between the transacts and the soil evolution. Of the studied profiles and sections, seven soil profiles were selected as control for which the experimental results and classification outcomes were presented. Soil samples were transferred to the laboratory and the parameters EC, pH, texture, lime percentage, saturation percentage, and organic carbon percentage were measured by the following methods:

-Soil texture: Soil texture is determined by hydrometric method using 10% sodium polyphosphate to disperse soil particles and readings in 40 seconds and 2 hours.

-Lime: It was measured by calcimetric method and the volume of CO_2 released due to a certain amount of reaction from dry soil with hydrochloric acid.

-Soil acidity: was measured using a pH meter.

-Electrical conductivity: was measured by an electrical conductivity meter.

-Organic carbon: Organic carbon was measured by the Walkly and Blake method.

3. Results

The components of the land unit have special features that are briefly stated. Also, the classification of soils is based on the 2014 key .(of soil taxonomy (Figure 4

3.1. Land component

3.1.1 Land unit components 2.1.1 (2: Hill, 1: Formation of limestone and dolomitic limestone thick layer and 1: jungle)

This unit consists of deep evolved soil. Gypsum was washed from the horizons and the basic saturation percentage was more than 60 cm up to 100 cm without lime. Profile 1 is the control profile of this soil.

Classification of this soil: Fine loamy, mixed, mesic, Dystric Eutrudepts.

3.1.2 Land unit components 2.3.1 (2: Hill, 3: Shale bed, Sandstone, Siltstone, Clay, Quartzite sandstone, Conglomerate and 1: jungle)

It is a very deep soil with more than 3% organic matter in the surface horizon, which is gradually reduced. The soil texture is heavy, lacks gypsum, and lime has been transferred to the lower horizons. Profile 3 is the control profile of this soil.

Classification of this soil: Fine-loamy, mixed, mesic, Typic Hapludolls.

3.1.3 Land unit components 2.3.2 (2: Hill, 3: Shale bed, Sandstone, Siltstone, Clay, Quartzite sandstone, Conglomerate and 2: Rang)

The properties of this soil are similar to profile 3, but the percentage of materials to be

neutralized is higher. Profile 4 is the control profile of this soil.
Classification of this soil: Fine-loamy, mixed, mesic, Typic Hapludalls.

3.1.4 Land unit components 2.4.1 (2: Hill, 4: Marl bedrock, calcareous marl, and light green ammonite marl limestone and 1: jungle)

It is a deep, relatively evolved soil with a heavy texture and cubic structure and without gypsum and lime, which has been largely transferred to the lower horizons. Profile 2 is the control profile of this soil.
Classification of this soil: Fine-loamy, mixed, mesic, Vertic Eutrudepts.

3.1.5 Land unit components 2.5.2 (2: Hill, 5: Valley filling deposits include alluvial fans, alluvial barracks, and 2: agriculture)

It is a very deep soil with a heavy texture, accumulation of lime in the lower horizons, and organic carbon more than 1.5% in the surface horizon, which gradually decreases. Profile 5 is the control profile of this soil.
Classification of this soil: Fine-loamy, mixed, mesic, Fluventic Calciudolls.

3.1.6 Land unit components 2.5.3 (2: Hill, 5: Valley filling deposits include alluvial fans, alluvial barracks, and 3: Range)

It is a very deep soil with a very heavy texture and the transfer of lime to the lower horizons. Organic carbon in the surface horizon is more than 1%, which gradually decreased. Profile 6 is the control profile of this soil.
Classification of this soil: Fine-loamy, mixed, mesic, Typic Calciudolls.

3.1.7 Land unit components 2.5.1: (2: Hill, 5: Valley filling deposits include alluvial fans, alluvial barracks, and 1: jungle)

It is a very deep soil with very little evolution and gravel. The soil texture is very heavy and has a regular reduction of organic carbon with depth. Profile 7 is the control profile of this soil.
Classification of this soil: Clayey-Skaletal, mixed, Typic Udorthents.

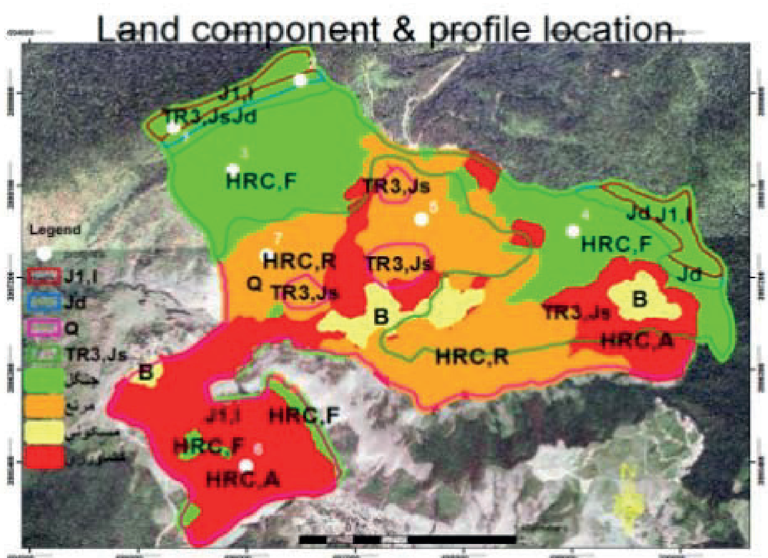

Figure 4. Geological formations, land use, and location of control profiles

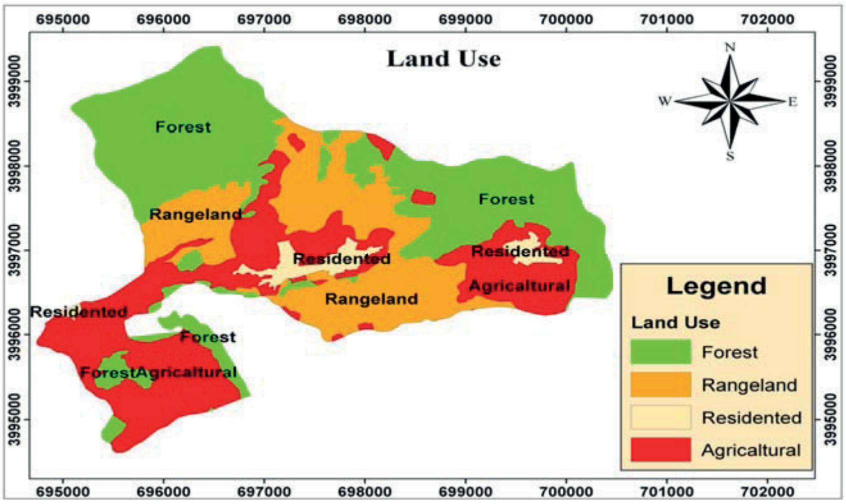

Figure 5. Land use of region

3.2. Land use

The main land uses in the region are forests, rangelands, agricultural lands and residential areas, each of which has its own effect on soil formation and evolution. Figure 5 shows the land uses.

The climate in the region is almost the same and its effect on the soil is similar. However, what has even alleviated the impact of climate and formed a variety of soils in the region is the diversity of geological formations, slope, and relief. This is consistent with the findings of Aliolad *et al*. (2010) in Khairudkenar region. To investigate the effect of land use on the physical and chemical properties of soil, as mentioned, the analysis of variance test was performed. Table 2 was prepared using the laboratory results of all soil samples from the study profiles and sections. Table 3 shows the results of one-way analysis of variance. According to the table, the significance is more than 5% in all physical and chemical properties of soil and thus, there is no significant difference between different land uses in terms of soil properties at the 95% level. Therefore, it can be concluded that different land uses in the region have not had a particular impact on changing the physical and chemical properties measured in this area, and therefore, geological formations and relief are two major factors for the formation of various soils in the region.

Although there was no statistically significant difference between different land uses in terms of physicochemical properties, there was a numerical difference and the continuation of this land use change in the region in the upcoming years will find a statistically significant difference. In addition, this lack of change may imply the soil uniformity in the past, and what has changed the classification of soils in the current situation is mainly the change in the thickness of the mollic horizon.

5. Discussion

In this study, the soil organic carbon has the highest amount in forest lands, and this amount decreased in the deforested lands, especially in agricultural lands. The changes of soil organic

Table 2. Laboratory results of control profiles

Land Use	Profile	Depth	Horizon	SP	EC ds/m	pH	TNV	OM%	Nکل	p	k	Clay%	Silt%	Sand%
Forest	1	0-12	A	63.7	0.8	7.6	5.2	1.9	1.0	24.2	428.3	35.4	42.4	22.2
		12-33	BW	63.9	0.9	7.6	4.9	1.3	1.0	19.1	302.7	39.4	38.4	22.2
		33-80	Be	60.1	0.6	7.6	5.1	0.86	__	__	__	39.4	40.4	20.2
		80-120	C	60.5	0.6	7.5	4.8	0.86	__	__	__	39.4	40.4	20.2
Forest	2	0-20	A	65.8	1.1	7.9	3.7	2.4	0.13	26.5	496.8	37.4	44.4	18.2
		20-48	BW1	63.8	0.9	7.7	3.5	1.7	0.1	23.9	432.1	35.4	42.4	22.2
		48-70	BW2	64.5	0.6	7.5	3.6	1.2	__	__	__	35.4	42.4	22.2
		70-125	BSS	64.1	0.6	7.5	3.3	0.86	__	__	__	33.4	44.4	22.2
		>125	C	65.6	0.5	7.5	37.2	0.51	__	__	__	32.4	44.4	18.2
Agriculture with rangeland	3	0-18	A	65.1	1.8	7.8	3.6	3.6	0.2	32.1	525.7	35.4	46.4	18.2
		18-60	BW1	65.5	1.8	7.8	3.7	3.1	0.18	28.7	500.2	35.4	46.4	18.2
		60-120	BW2	65.3	1.6	7.8	3.8	2.5	0.14	27.2	486.3	35.4	46.4	18.2
		>120	BW3	60.4	1.2	7.7	3.4	1.9	0.11	24.1	421.7	35.4	40.4	24.2
Forest	4	0-19	A	62.9	0.8	7.6	14.2	1.7	0.1	23.8	429.5	33.4	44.4	22.2
		19-50	BW1	62.8	0.8	7.6	10.3	1.5	0.08	18.7	414.2	33.4	44.4	22.2
		50-90	BW2	60.1	0.7	7.6	14.4	0.68	__	__	__	33.4	40.4	26.2
		>90	R	__	__	__	__	__	__	__	__	__	__	__
Agriculture	5	0-25	A	63.8	1	7.8	8.6	1.5	0.18	28.5	512.8	37.4	42.4	20.2
		25-49	BW	64.1	1	7.8	6.9	2.4	0.14	26.9	476.9	35.4	42.4	22.2
		49-90	BK1	59.1	0.7	7.6	22.3	1.3	__	__	__	39.4	36.6	24.2
		90-120	BK2	60.8	0.7	7.6	26.8	1.03	__	__	__	39.4	36.4	24.2
Rangeland	6	0-20	A	65.3	1.5	7.5	4.6	2.2	0.12	25.6	486.5	37.4	44.2	18.4
		20-43	BW	65.7	1.1	7.5	18.4	1.5	0.09	20.2	481.3	37.4	44.2	18.4
		43-70	BK1	63.9	0.9	7.6	22.5	1.03	__	__	__	39.4	38.2	22.4
		70-130	BK2	63.8	0.7	7.6	27.4	0.86	__	__	__	39.4	38.2	22.4
Forest	7	0-12	A	65.7	0.9	7.7	2.9	1.9	0.18	23.9	433.2	37.4	42.2	18.4
		12-27	AC	65.3	0.6	7.5	3.8	1.5	0.18	18.8	385.6	39.4	42.2	18.4
		27-65	C	59.3	0.5	7.5	25.1	0.51	__	__	__	35.4	38.2	26.4

carbon are an important indicator of soil quality to assess the impact of management practices on the cultivated and forest lands (Mendham *et al*., 2004; Mohamad Asgari *et al*., 2014). Merino *et al*. (2004), Abera and belachew (2011), and Boroumand *et al.* (2014) showed that the land use change has significantly reduced the soil organic carbon in agricultural lands. Nael *et al*. (2004) stated in a study that due to the destruction of natural forests in Kohgiluyeh-Boyer-Ahmad province, the amount of soil organic carbon has decreased

Table 3. Results of one-way analysis of variance between three land uses, forest, rangeland, and agriculture, in terms of soil characteristics

Factor under study	Significance Level (%)	Sig (significance value)	Description
Acidity	5	0.834	There is no significant difference between the three land uses of this basin in terms of acidity.
Electrical conductivity	5	0.560	There is no significant difference between the three land uses of this basin in terms of electrical conductivity.
Organic carbon	5	0.664	There is no significant difference between the three land uses of this basin in terms of organic carbon content.
Clay percentage	5	0.380	There is no significant difference between the three land uses of this basin in terms of clay percentage.
Sand percentage	5	0.075	There is no significant difference between the three land uses of this basin in terms of sand percentage.
Silt percentage	5	0.063	There is no significant difference between the three land uses of this basin in terms of silt percentage.
Percentage of neutralizers	5	0.053	There is no significant difference between the three land uses of this basin in terms of percentage of neutralizers.
Soil depth	5	0.378	There is no significant difference between the three land uses of this basin in terms of soil depth.

from 1.4% in forest soil to 1.67% in the soil of the degraded area. Vagen *et al*. (2006) in the study of the impact of deforestation and agriculture on soil properties in Madagascar found that the amount of soil organic carbon in the first year after the deforestation was 23.8, and in the first three years, it decreased, on average, 11.3 g/kg. Normally, the soils covered by permanent forests with a large volume of litter entering the soil have the highest amount of organic carbon. On the other hand, in the deforested lands, organic matter is oxidized and decomposed due to aggregate degradation (Mendham *et al*., 2004). Chibsa and Taha (2009) in a study in Ethiopia concluded that in forest soils, due to lack of cultivation and abundant litter, there is a balance between rapid decomposition of soil organic matter and rapid accumulation of litter, but in agricultural lands, this balance is not visible. The most important factor that accelerates the reduction of organic matter in the soil is the cultivation, which increases the decomposition of organic matter during the plowing operations (Six *et al*., 2000). Lemenih *et al*. (2005) reported that cultivation causes a significant reduction in soil

carbon content. The reduction in the amount of organic carbon in rangeland soils can also be due to the removal of plants by livestock and, as a result, the reduced amount of litter added to the soil (Ahmadi *et al.*, 2003).

Soil acidity not only determines the acidity or alkalinity of the soil, but also estimates the capability to use essential elements and the toxicity of other elements through the relationship with pH. As such, with increasing the soil pH, the solubility of nutrients such as phosphorus, iron, zinc, and manganese decreases (Thomas, 1982). In forest and rangeland uses, especially in forest use, due to the greater penetration depth of the roots of forest trees and rangeland plants and their higher density, in the same conditions of precipitation, deep water penetration into the soil is higher and the further leaching reduced the percentage of equivalent calcium carbonate in surface soil and lowered the pH on the surface of the soils. These results are consistent with the results obtained by Shamsi Mahmoudabadi *et al.* (2011).

The role of humans in cutting down forest trees and occupying the lands around residential areas is one of the factors affecting the situation of soils in the current conditions (Rezaei and Gilkes, 2005). Mollic horizon is usually lost in the lands around the settlements due to erosion and the soils have shifted from mollisols to inceptisols and even entisols.

The soils of the region can be divided into different groups:

1. In-situ soils
2. Disturbed alluvial soils.

The soils formed on Lar (l1J), Delichai (jd) and Shemshak formations (TR3.JS) are in-situ soils. Despite the forest cover, these lands are located on a very steep slope. Although the Lar and Delichai formations are mostly calcareous, they have not greatly evolved in this area due to the very steep slopes and are classified as inceptisols. However, the slope in Shemshak formation is relatively gentle with forest cover and less displacement in the surface horizon to provide sufficient opportunity for the horizontal formation of mollic and mollisols, which was consistent with the studies of Rezaei and Gilkes (2005) and Asghari and Shahab Arkhazloo (2020) who stated that many soil properties, such as effective pedon thickness, water retention capacity, and percentage of coarse aggregates are significantly dependent on the slope.

The deposits located in the valleys of the mountains and hills belonging to the Quaternary, which were formerly forest and have now been turned into rangelands, the mollic horizon is still preserved if the slope of the lands was low, and the limestone of the parent materials has been transferred to the lower horizons and formed the calcic horizon. This finding is consistent with the studies of Pajand *et al*. (2016) who stated that at the slopes less than 15%, the amount of equivalent calcium carbonate in the northern direction was significantly higher than that in the southern direction, and therefore, slope affects the percentage of lime in the soil. This part of the land has mollisols, which are mainly classified in the large Calciudolls group according to the soil moisture regime. In sloping lands, due to topsoil erosion, the mollic horizon is lost and the soils are classified as entisols and large Udorthents group. In these lands, as the topsoil erodes, the subsurface rocks and aggregates appeared in the soil profile.

Conclusion

The study area was located in the middle of the Hyrcanian Forest, and evidence showed that the development of temporary settlements for animal farmers and deforestation of the land into villages and settlement areas have destroyed the neighboring forest areas and contributed to the development of pastures and farmlands.

A comparison between the soils covering the occupied lands and the forest areas showed a dramatic declining trend in the soil properties. In this respect, the farmlands were dominantly covered by antisols while the pastures were most often covered by inceptisols and the forests were dominated by mollisols; these showed the soil variations under similar natural conditions as a result of the changes in the land use. It is recommended to set the scene to not only limit the deforestation process, but also suit the pastures for natural forestation in an attempt to prevent further erosion of the invaluable soil and preserve the even more valuable natural resources.

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