J. Agr. Sci. Tech. (2011) Vol. 13: 727-742

Assessing Impacts of Land Use Change on Soil Quality Indicators in a Loessial Soil in Golestan Province, Iran

S. Ayoubi[1]*, F. Khormali[2], K. L. Sahrawat[3], A. C. Rodrigues de Lima[4]

ABSTRACT

A study was conducted to determine suitable soil properties as soil quality indicators, using factor analysis in order to evaluate the effects of land use change on loessial hillslope soils of the Shastkola District in Golestan Province, northern Iran. To this end, forty surface soil (0-30 cm) samples were collected from four adjacent sites with the following land uses systems: (1) natural forest, (2) cultivated land, (3) land reforested with olive, and (4) land reforested with Cupressus. Fourteen soil chemical, physical, and biological properties were measured. Factor analysis (FA) revealed that mean weight diameter (MWD), water stable aggregates (WSA), soil organic matter (SOM), and total nitrogen (TN) were suitable for assessing the soil quality in the given ecosystem for monitoring the land use change effects. The results of analysis of variance (ANOVA) and mean comparison showed that there were significant (P< 0.01) differences among the four treatments with regard to SOM, MWD, and sand content. Clearing of the hardwood forest and tillage practices during 40 years led to a decrease in SOM by 71.5%. Cultivation of the deforested land decreased MWD by 52% and increased sand by 252%. The reforestation of degraded land with olive and Cupressus increased SOM by about 49% and 72%, respectively, compared to the cultivated control soil. Reforestation with olive increased MWD by 81% and reforestation with Cupressus increased MWD by 83.6%. The study showed that forest clearing followed by cultivation of the loessial hilly slopes resulted in the decline of the soil quality attributes, while reforestation improved them in the study area.

Keywords: Factor analysis, Land use change, Reforestation, Soil quality.

INTRODUCTION

Environmental degradation caused by inappropriate land use is a worldwide problem that has attracted attention in sustainable agricultural production systems (Pierce and Larson, 1993; Zink and Farshad, 1995; Hurni, 1997; Hebel, 1998; Sanchez-Maranon *et al*., 2002; Vagen *et al*., 2006; Khormali and Nabiollahy, 2009). During the recent decades, soil quality concept has emerged and is used to assess land or soil quality under various systems (Doran and Parkin, 1994; Karlen *et al*., 1997; de Lima *et al*., 2008). Soil quality essentially means "the capacity of a soil to function" (Larson and Pierce, 1991; Doran and Parkin, 1994; Karlen *et al*., 1997).

Larson and Pierce (1991) outlined five soil functions that may be used as the criteria for judging the soil quality: to hold and release water to plants, streams, and subsoil; to hold

[1] Department of Soil Science, College of Agriculture, Isfahan University of Technology, 84156-83111, Isfahan, Islamic Republic of Iran.
* Corresponding author, e-mail: ayoubi@cc.iut.ac.ir
[2] Department of Soil Science, College of Agriculture, Gorgan University of Agricultural Sciences and Natural Resources, Gorgan, Islamic Republic of Iran.
[3] International Crop Research Institute for the Semi Arid Tropics (ICRISAT), Patancheru 502 324, Andhra Pradesh, India.
[4] Farm Technology Group, Wageningen University, P. O. Box: 17, 6700 AA Wageningen, The Netherlands.

[DOR: 20.1001.1.16807073.2011.13.5.13.4]

and release nutrients and other chemicals; to promote and sustain root growth; to maintain suitable soil biotic habitats; and to respond to management and resist degradation. It is suggested that, for practical purposes, soil quality can be used to judge impact on crop yield, erosion, ground and surface water status and quality, food and air quality (Wang *et al*., 2003).

The capacity of the soil to function can be determined by soil physical, chemical, and biological properties, also termed as soil quality indicators (Shukla *et al*., 2006; Wang and Gong, 1998). Soil properties that are responsive to the change in the land use dynamics on a short-term are considered as suitable soil quality indicators (Carter *et al*., 1998). A soil quality indicator is a measurable soil property that affects the capacity of a soil to perform a specified function (Karlen *et al*., 1997). For evaluation of soil quality, it is desirable to select indicators that are directly related to soil quality. If a set of attributes is selected to represent the soil functions and if the appropriate measurements are made, the data may be used to assess the soil quality (Heil and Sposito, 1997).

A large body of information is now available that clearly shows that severe decline in soil quality occurs along with increased soil erosion as a result of agricultural activities following deforestation (Sigstad *et al.*, 2002). Hajabbasi *et al.* (1997) showed that deforestation and clear cutting of the forest in central Zagrous mountains (western Iran) resulted in a lower soil quality and, consequently, decreased productivity.

Ellingson *et al*. (2000) quantified soil N dynamics: mineralization and nitrification rates in response to the change in land use from forest to pasture. However, they represented the high-end extreme as a large proportion of the above ground forest biomass was consumed by anthropogenic fires. Land use changes, especially cultivation of deforested land, may rapidly diminish soil quality. As a result, severe degradation in soil quality may lead to a permanent degradation of land productivity (Kang and Juo, 1986; Nadri *et al*., 1996; Islam *et al*., 1999; Islam and Weil, 2000b).

Due to an increasing demand for firewood, timber, pasture, food, and residential dwelling, the hardwood forests are being degraded or converted to cropland at an alarming rate in the hilly regions of Golestan Province, during the last few decades. The forest coverage in this province has decreased by 32.2% (from 18 to 12.2 million ha) in the last 30 years (Kiani *et al*., 2003). This conversion of natural forest to other uses, such as cultivation, has created serious problems and is a main cause of the annual destructive flooding in this area (Mosaedi, 2003; Ajami *et al*., 2006).

The study region is located in north-facing slopes of Alborz Mountain Ranges and was covered with hardwood forests of *Parotia pers*ica and *Carpinus betulus* up to 40 years ago. The parent material in the lower hill slopes of Golestan Province are composed of loess materials, which are very susceptible to soil erosion and need to be properly managed (Kiani *et al.*, 2003). While signs of rill, gully, and even landslide erosion patterns induced by improper conservation practices in the deforested land are evident on the hill slopes (Ayoubi, 2005), degraded land has been reclaimed by reforestation with *Olea europea* and *Cupressus arizonica* by local farmers and governmental organizations, during the last 30 years.

Although there are a lot of data available on soil properties due to land use change, little information is available for the soils developed on the loess material in the semi-arid region. No attempt has been made to generate minimum data set to evaluate soil quality changes following the deforestation and reforestation. The objectives of this study were to: (1) generate a minimum data set (MDS) on soil quality indicators using factor analysis and (2) evaluate the changes in the selected soil quality indicators in response to land use changes.

[DOR: 20.1001.1.16807073.2011.13.5.13.4]

MATERIALS AND METHODS

Description of the Study Area

The study area is located between 36° 24´´ and 38° 5´´ northern latitudes, and 53° 51´´ and 56° 14´´ eastern longitudes, 10 km east of Gorgan City, in northern Iran (Figure 1). The parent material is composed mainly of loess material, highly sensitive to erosion and has a hilly physiographic landform with 20-25% slope. The average annual rainfall is 560 mm and occurs mainly from October to April. The annual average temperature at the site is 14.9ºC. The average elevation of the hillslope is 320 m above sea level. According to Soil Taxonomy (Soil Survey Staff, 2006), the soil moisture and temperature regimes are xeric and thermic.

The hill slopes of the study area have been generally covered with hardwood dominated by *Parotia persic*a and *Carpinus betulus* trees. The selected site on the steep slopes was opened by clear cutting and converted to farmlands, about 40 years ago. In some areas, the reforestation with *Cupressus arizonica* and *Olea europea* was introduced by local farmers and governmental organizations during the last 30 years. Details of the selected land uses are given in Table 1. The soils of the study area are classified as Mollisols and Inceptisols (Soil Survey Staff, 2006) with textures ranging from silt and silt loam to silty clay loam in the surface of different land uses.

The study included four adjacent land parcels under different uses at the Shastkola: (1) natural hardwood forest, (2) cultivated land, (3) reforested land with *Olea europea,* and (4) reforested land with *Cupressus arizonica*, as in Figure 1.

Soil Sampling and Pretreatments

Surface soil samples from 0-30 cm depth were collected in April 2005 from forty randomly selected points in the four adjacent land parcels, using a hand auger. In total, 160 samples were collected, air-dried and passed through a 2 mm sieve to remove stones, roots, and large organic residues before conducting analyses for chemical and physical characteristics. In order to measure soil microbial respiration rate, 40 fresh and undisturbed soil samples were taken from each land parcel.

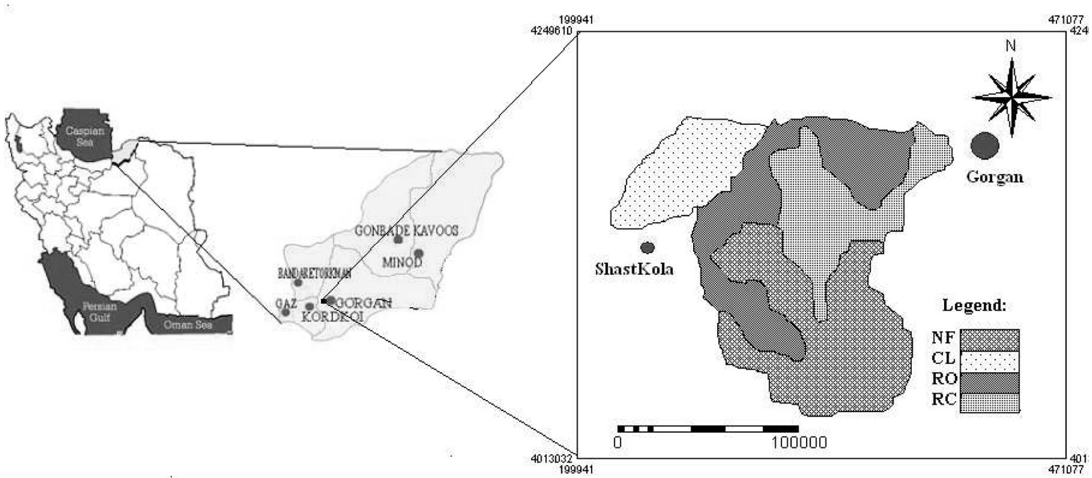

Figure 1. Location of the study site in north of Iran.

Table 1. Description of the site under different land uses on losseial soil in the Gorgan Province, northern Iran.

Land use	Soil classification (USDA, 2006)	Slope %	Parent material	Age of treatment	Geomorphic positions	Aspect
Natural Forest	Typic Calcixerolls	10-25	Loess	Native	Back slope-Foot slope	N-NE
Cultivated land	Typic Haploxerepts	10-20	Loess	40 years	Back slope-Foot slope	N-NE
Reforested(*Olea*)	Typic Haploxerepts	10-20	Loess	10 years	Back slope-Foot slope	N
Reforested(*Cupressus*)	Typic Haploxerepts	10-25	Loess	30 years	Back slope-Foot slope	N-NE

Analyses of Soil Samples

Physical Properties

The soil samples collected by a cylindrical metal sampler (core diameter 100 mm), were oven-dried at 105° C for 24 hours and weighed to calculate bulk density (Blake and Hartage, 1986). Particle size distribution was determined by the Bouyoucos hydrometer method (Gee and Bauder, 1986). The wet sieving method of Angers and Mehuys (1993) was used with a set of sieves of 2.0, 1.0, 0.5, 0.25 and 0.1 mm diameter. Approximately, 50 g of soil sieved through 4.6 mm was put on the first sieve of the set and gently moistened to avoid a sudden rupture of soil aggregates. The set was sieved in distilled water at 30 oscillations per minute for 10 minutes and the resistant aggregate on each sieve were dried at 105°C for 24 hours, weighted and corrected for sand fraction to obtain the proportion of the true aggregates. The mass of < 0.1 mm fraction was obtained by difference. The method of van Bevel (1949) as modified by Kemper and Rosenau (1986) was used to determine water stable aggregates (WSA) and *MWD*.

The WSA % was calculated using Equation (1) as follows:

$$WSA = \frac{(M_{(a+s)} - M_s)}{(M_t - M_s)} \times 100 \qquad (1)$$

Where $M_{(a+s)}$ is the mass of resistant aggregates plus sand (g), M_s is the mass of the sand fraction alone (g), and M_t is the total mass of the sieved soil (g). The *MWD* was determined as follows:

$$MWD = \sum_{i=1}^{n} X_i W_i \qquad (2)$$

Where *MWD* is the mean weight diameter of water stable aggregates, X_i is the mean diameter of each size fraction (mm), and W_i is the proportion of the total sample mass in the corresponding size fraction after deducing the mass stone as indicated above.

Soil erodibility factor i.e. K factor in the Universal Soil Loss Equation, was calculated according to Wischmeier and Smith (1978). Available water holding capacity (AWHC) was determined as the difference between field capacity and permanent wilting point (Klute and Dirksen, 1986). Water retention at field capacity (-33kPa) and at permanent wilting point (-1500 kPa) were determined using high-range pressure plate extractor (Soil Moisture Equipment Corp) equipped with a ceramic plate.

Chemical Properties

Soil pH was measured in saturated soil using glass electrode (Mclean, 1982) and electrical conductivity (EC) was measured in the saturated paste using conductivity meter (Rhoades, 1982). Calcium carbonate ($CaCO_3$) was measured by the Bernard's calcimetric method (Chaney and Slonim, 1982). Soil organic matter (SOM) was determined using a wet combustion method (Nelson and Sommers, 1982) and total nitrogen (TN) was determined by the Kjeldahl method (Bremner and Mulvaney, 1982).

Biological Properties

Microbial respiration rate (MR) was measured by the closed bottle method of Anderson (1982). Soil samples (moistened to about 30% of filed capacity) were transferred to a bottle with a glass test tube containing an alkali solution (1.0N NaOH); the bottle was closed and maintained at 25ºC for seven days. The trapped CO_2 was calculated as a function of soil respiration by titration of the contents of the test tube with HCl after $BaCl_2$ pretreatment

Statistical Analysis

Descriptive statistics in the form of mean, standard deviation (SD), minimum, maximum, median, coefficient of variation (CV), distribution of normality, range, skewness and kurtosis were determined (Wendroth *et al*., 1997). The CV was used to describe the amount of variability for each soil parameter. Pearson linear correlations among various soil parameters were calculated using SPSS software (Swan and Sandilands, 1995) and were used to establish relationships among the soil variables.

Factor analysis was used to group the 14 soil variables into factors based on the correlation matrix of the variables using FACTOR module and the principal component analysis method of factor extraction in SPSS software (Brejda *et al*., 2000). Principal component analysis was used as the method of factor extraction because it required no prior estimates of the amount of variation of each soil variable that would be explained by the factors. The maximum number of factors possible is 14, which is equal to the number of variables. Only factors with eigen value >1 were retained (Brejda *et al*., 2000). Also, one-way ANOVA and mean comparison using Duncan's test were conducted using the SPSS software.

RESULTS AND DISCUSSION

Statistical Descriptions

Summary of the measured soil properties including mean, median, standard deviation, coefficient of variation, range, skewness and kurtosis coefficients, are given in Table 2. The descriptive statistics of soil data suggested that they were all normally distributed because the skewness values were within the range of -1 to +1 (Swan and Sandilands, 1995) (Table 2). Some researchers, however, have suggested that, in disturbed ecosystems, some soil variables show skewed distributions (Nael *et al*., 2004; Wang *et al*., 2003). Skewness values of soil properties in the cultivated land showed low deviation from normal distribution. Coefficient of variation for all of the variables was low, with the highest and lowest CV's related to sand (0.29-0.51) and pH (0.01-0.03), respectively. In general, the CV values for the selected soil properties of the cultivated land were lower than those reported in the literature, probably due to the homogenizing effect of the long-term cultivation under similar soil management practices. This finding is also in accordance with those reported by Paz Gonzalez *et al*. (2000).

Factor Analysis

The linear correlation analysis of the 14 soil attributes, which represent soil physical, chemical, and biological properties for the study area, showed a significant correlation among 77 of the 91 soil attribute pairs ($P< 0.01$, and $P< 0.05$) (Table 3). Statistically significant positive correlations were obtained for the total nitrogen versus SOM, and *MWD* versus *WSA* ($r> 0.90$).

Table 2. Summary of the statistics for selected soil physical, chemical, and biological properties in all land uses in Golestan Province, Northern Iran (N= 40).

Variable	Unit	Land use	Mean	Min	Max	Median	S.D	CV	Range	Skewness	Kurtosis
Sand	%	NF[h]	10.5	4.8	26.4	9	2.3	0.22	21.6	0.7	3.0
		CL[i]	37.0	7.2	65	36.7	19.2	0.51	57.8	-0.5	-0.80
		RO[j]	25.3	14	45	23	9.9	0.39	31	0.8	0.06
		RC[k]	13.6	5.2	25	12.6	6.3	0.46	19.8	-0.14	1.88
Silt	%	NF	77.3	63.1	86.4	78.5	6.65	0.09	23.3	-0.8	1.50
		CL	40.8	15.5	71.3	39.8	17	0.41	55.8	-0.5	-0.80
		RO	56.6	32.7	66.6	59.9	11.4	0.20	33.9	-1.0	-0.09
		RC	54.4	43	64.8	58.2	5.9	0.10	21.8	-1.0	1.88
Clay	%	NF	12.2	8.0	20.5	10.5	4.0	0.33	12.5	0.9	0.68
		CL	22.2	11.5	37.5	19.5	8.4	0.38	26	1.0	0.15
		RO	18.1	15.5	31.5	19.5	4.8	0.26	16	1.0	1.87
		RC	32	18	38	29.9	5.7	0.18	20	-0.4	0.80
BD[a]	g cm^{-3}	NF	1.24	1.03	1.49	1.25	0.13	0.10	0.46	0.15	-1.24
		CL	1.53	1.42	1.66	1.54	0.07	0.04	0.25	0.08	-0.98
		RO	1.47	1.18	1.55	1.36	0.1	0.07	0.37	0.23	-0.71
		RC	1.36	1.31	1.64	1.45	0.09	0.06	0.33	-0.02	-0.79
K-factor	-	NF	0.12	0.08	0.19	0.15	0.03	0.23	0.11	0.99	1.01
		CL	0.36	0.23	0.44	0.39	0.09	0.25	0.21	-0.99	0.67
		RO	0.23	0.18	0.28	0.19	0.07	0.30	0.10	0.03	1.50
		RC	0.24	0.16	0.26	0.23	0.06	0.25	0.10	-0.87	-0.34
AWHC[b]	% Vol	NF	0.19	0.13	0.21	0.17	0.02	0.10	0.08	-0.98	1.02
		CL	0.11	0.07	0.13	0.09	0.03	0.27	0.06	-0.8	1.33
		RO	0.15	0.08	0.18	0.16	0.03	0.20	0.10	0.23	0.32
		RC	0.16	0.09	0.20	0.17	0.02	0.12	0.11	0.11	-0.54
WSA[c]	%	NF	92	78	95	93	32.2	0.35	17	0.99	2.50
		CL	54	34	64	56	21.6	0.40	30	0.02	0.50
		RO	67	59	72	62	16.7	0.25	13	0.11	0.99
		RC	78	71	85	72	23.4	0.30	14	0.06	1.10
MWD[d]	mm	NF	2.42	1.7	3.03	2.4	0.4	0.16	0.41	-0.28	-0.78
		CL	1.16	0.14	1.65	1.17	0.26	0.22	0.81	0.24	-0.83
		RO	2.10	1.3	2.73	2.2	0.46	0.21	1.43	-0.46	-0.86
		RC	2.13	1.68	2.59	2.13	0.25	0.11	0.91	-0.42	0.76
SOM[e]	%	NF	6.45	5.07	7.53	6.36	0.65	0.1	2.46	-0.5	-0.47
		CL	1.84	0.94	2.81	1.91	0.54	0.29	1.87	0.04	-0.79
		RO	2.75	1.56	3.82	2.81	0.64	0.23	2.26	-0.09	-0.61
		RC	3.17	1.79	4.65	3.15	0.64	0.2	2.77	-0.08	0.16
pH	-Log[H^+]	NF	7.21	6.9	7.4	7.2	0.12	0.01	0.5	-0.64	-0.05
		CL	7.61	7.41	7.33	7.63	0.1	0.01	0.32	0.77	-0.56
		RO	7.53	7.28	7.8	7.63	0.14	0.02	0.52	0.13	0.99
		RC	7.29	6.86	7.68	7.3	0.2	0.03	0.82	-0.27	1.0.1
EC	dS/m	NF	1.1	0.54	1.95	0.87	0.32	0.29	1.4	0.7	2.9
		CL	1.01	0.51	1.77	0.83	0.37	0.37	1.26	0.91	0.04
		RO	1.2	0.74	1.99	1.0	0.38	0.32	1.25	0.56	-0.95
		RC	0.99	0.74	1.62	1.17	0.23	0.19	0.87	0.002	-0.52
TN[f]	%	NF	0.92	0.72	1.08	0.91	0.09	0.10	0.35	-0.06	-0.46
		CL	0.28	0.13	0.4	0.27	0.07	0.25	0.27	-0.05	-0.79
		RO	0.39	0.22	0.55	0.40	0.09	0.23	0.32	-0.09	-0.61
		RC	0.45	0.26	0.65	0.45	0.09	0.20	0.4	-0.09	0.93
$CaCO_3$	%	NF	4.16	2.4	6.8	4.2	1.15	0.27	4.4	0.63	0.04
		CL	14.59	12	16.85	13.26	1.25	0.09	4.85	0.93	0.87
		RO	13.87	11.11	15.78	15.2	1.27	0.09	4.76	-0.57	-0.21
		RC	10.04	7.96	11.76	10.03	0.8	0.07	3.8	-0.54	2.25
MR[g]	(mg CO_2 g^{-1} soil day^{-1})	NF	0.75	0.7	0.79	0.74	0.02	0.02	0.09	0.33	-0.25
		CL	0.24	0.19	0.3	0.24	0.028	0.11	0.11	0.37	0.35
		RO	0.42	0.38	0.49	0.42	0.02	0.04	0.11	0.06	0.92
		RC	0.31	0.19	0.3	0.24	0.03	0.11	0.11	0.37	0.35

[a] Bulk Density; [b] Available Water Holding Capacity; [c] Water Stable Aggregate; [d] Mean Weight Diameter; [e] Soil Organic Matter; [f] Total Nitrogen; [g] Microbial Soil Respiration Rate; [h] Natural Forest; [i] Cultivated land; [j] Reforested with Olive, [k] Reforested with Cupressus.

Table 3. Pearson's correlation coefficients among measured soil properties in the 0-30 cm soil layer under different land uses in Golestan Province, northern Iran (N= 160).

	SAND	SILT	CLAY	TN	MWD	K factor	WSA	AWHC	$CaCO_3$	SOM	MR	EC	pH	TN
SAND	1													
SILT	-0.89**	1												
CLAY	-0.05	-0.38**	1											
BD[a]	0.41**	-0.55**	0.38**	1										
MWD[b]	-0.52**	0.54**	-0.13	-0.51**	1									
K factor[c]	0.24**	-0.29**	0.15	0.58**	-0.61**	1								
WSA[d]	-0.52**	0.54**	-0.13	-0.51**	0.95**	-0.61**	1							
AWHC[e]	-0.58**	0.38**	0.34**	-0.35**	0.49**	-0.39**	0.49**	1						
$CaCO_3$	0.54**	-0.42**	-0.17*	0.43**	-0.69**	0.51**	-0.68**	-0.52**	1					
SOM[f]	-0.47**	0.66**	-0.49**	-0.68**	0.86**	0.70**	0.82**	0.42**	-0.32**	1				
MR[g]	-0.36**	0.62**	-0.63**	-0.76**	0.54**	-0.63**	0.54**	0.32**	-0.25**	0.91**	1			
EC	-0.06	0.01	0.10	-0.14	0.22**	-0.38**	0.21**	0.08	-0.46**	0.05	0.06	1		
pH	0.40**	-0.36**	-0.01	0.34**	-0.46**	0.51**	-0.46**	-0.49**	0.32**	-0.50**	-0.41**	-0.11	1	
TN[h]	-0.57**	0.69**	-0.59**	-0.71**	0.62**	0.75**	0.62**	0.55**	-0.45**	0.92**	0.81**	0.08	-0.58**	1

[a] Bulk Density; [b] Mean Weight Diameter; [c] Soil erodibility factor; [d] Water Stable Aggregate; [e] Available Water Holding Capacity; [f] Soil Organic Matter; [g] Microbial Soil Respiration Rate, [h] Total Nitrogen.

The highest negative correlation was obtained for sand versus silt (r= -0.89). Results showed that there was a high correlation among physical properties such as BD, *MWD*, and *WSA*, and among the various chemical properties such as SOM and the measured soil respiration (MR) (Table 3). BD was negatively correlated with most of the soil properties, unlike *WSA* and *MWD*, which were positively correlated with other soil characteristics. The findings by Islam and Weil (2000a) showed similar trend in the correlation coefficients for soil properties.

If soil sampling and analyses are properly conducted, the results should collectively show the land use effects (Wang *et al*., 2003). Attributes selected for assessment of soil characteristic induced by land use change must ideally account for most, if not all, of the variances. For the 14 soil properties measured, a maximum of 14 factors might explain the total variance of each factor that was defined as eigenvalue (Swan and Sandilands, 1995). An eigenvalue plot allows identification of the significant factors that collectively represent the major proportions of the total variability.

Factors 1, 2, and 3 are the most significant factors in explaining the system variance compared to the remaining factors. The first three factors have eigenvalues more than 1 (Table 4). The factors with eigenvalue> 1, were retained, since eigenvalue< 1 indicated that the factor could explain less variance than the individual attribute (Shukla *et al*., 2006). The first factor (Factor 1) explained 50.79% of the total variance. The second factor accounted for a further 15.86% of the total variance. Factors 1, 2, and 3 collectively accounted for 76.28% of the total variance. The inclusion of the next factor increased the cumulative variance by 7.08% up to 83.36%.

A factor, as an array of variables, holds contributions (in the forming of loadings or weights) from all of the selected 14 properties. The weights (loadings) for the first three factors are illustrated in Table 4. The magnitude of the eigenvalues was used as a criterion for interpreting the relationship between soil properties and factors. Soil properties were assigned to a factor for which their eigenvalues were the highest. Factor 1 explained 50.79% of the total variance with a high positive loading (> 0.85) from *MWD*, TN, *WSA*, and SOM (Table 4). Factor 1 included negative loading from sand and clay contents, BD, K factor, $CaCO_3$, and pH (Figure 2). The high positive loading from *MWD*, TN, *WSA*, and SOM were the results of the statistically significant correlation coefficients among the characteristics selected for the study (Table 3).

Factor 2 explained 15.85% of the total variance with high negative loading (-0.43) from clay content, *MWD* and *WSA* and high positive loading (> 0.4) from MR, TN and SOM (Table 4). It also had a moderate positive loading from MR (0.43), TN (0.49), and SOM (0.49) resulting from significant correlation among MR, TN, and SOM (Table 3). Factor 3 had high positive loading from sand content (0.72) and negative loading from silt content (-0.52), K factor (-0.32), and clay content (-0.28).

The relative importance of each soil attribute, in terms of its contribution to all of the factors, is judged by its communality value, a value that indicates the residual variance of the attribute in comparison to a critical convergence value of confidence (Joreskog, 1977). If the residual variance is less than the convergence value, the corresponding communality of the attribute is equal to 1. The three factors explained nearly 99% of variance in sand content, SOM, TN, *WSA*, and *MWD*; >84% in silt content and MR; > 60% in K factor; > 50% in CaCO3; < 50% in BD, clay content, AWHC, pH, and EC (Table 4). A high proportion of communality estimate suggests that a high portion of variance was explained by the factor; therefore, it would get higher preference over a low communality estimate (Shukla *et al*., 2006). Thus, EC was the least important attribute

Table 4. Proportion of variance, initial eigenvalues and communality estimates for soil properties in the 0-30 cm soil layer under different land uses in loessial soils of Golestan povince, nrthern Iran.

soil attributes	Factor			Communality estimates
	1	2	3	
SAND	-0.67663	-0.28967	-0.5702	0.99
SILT	0.768511	-0.10632	0.472002	0.87
CLAY	-0.31862	0.839708	0.112359	0.36
BD[a]	-0.76813	0.207423	0.107715	0.49
MWD[b]	0.821633	0.270165	-0.09152	0.99
K factor	-0.75879	-0.0473	0.471154	0.61
WSA[c]	0.821014	0.270342	-0.09107	0.99
AWHC[d]	0.597841	0.490413	0.27465	0.39
$CaCO_3$	-0.63891	-0.57709	0.154535	0.53
SOM[e]	0.881894	-0.35664	-0.00204	0.99
MR[f]	0.837238	-0.4714	-0.07693	0.84
EC[g]	0.224255	0.382505	-0.65648	0.05
pH	-0.61194	-0.17775	-0.04432	0.31
TN[h]	*0.881818*	-0.35665	-0.00191	0.99
Initial eigenvalue	7.11	2.22	1.34	-
Variance%	50.79	15.86	9.63	-
Cumulative variance%	50.79	66.65	76.28	-

[a] Bulck density; [b] Mean Weight Diameter; [c] Water Satble Aggregates; [d] Available Water Holding Capacity; [e] Soil Organic Matter; [f] Microbla Respiration; [g] Electrical conductivity, [h] Total Nitrogen.

[DOR: 20.1001.1.16807073.2011.13.5.13.4]

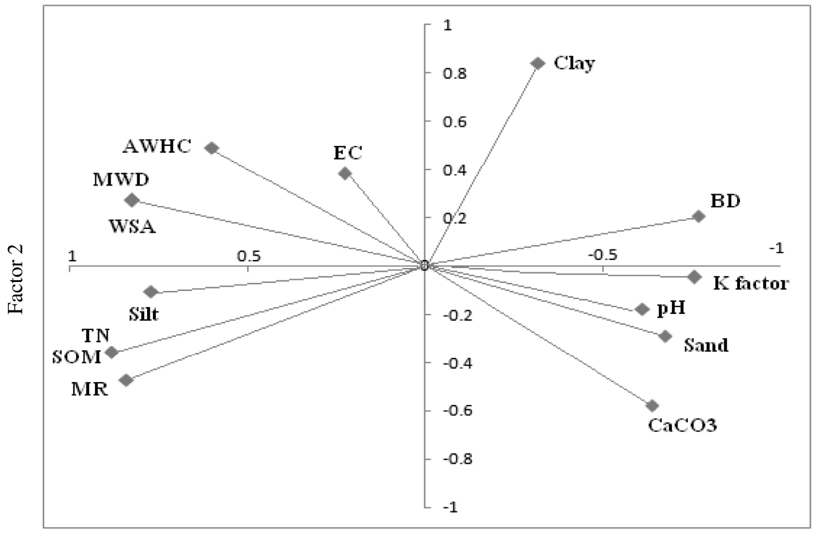

Figure 2. Loading plot indicating associations of soil properties to Factors 1 and Fcator 2 in the area studied.

due to the lowest communality estimate.

Mean score for Factor 1 was higher under natural forest than under cultivated land; whereas the score was not significant between land reforested with olive or with Cupressus land use (Table 5). Factors 2 and 3 had significant differences among natural forest, cultivated land, and reforested treatments. Land use affects the mean score, which is consistent with the results from the analysis of variance among the most appropriate soil properties as discussed in the following section.

Selection of the suitable soil properties for monitoring land use change should consider the properties that account for the most variability. Such data set would have a few soil properties for the practical assessment of soil quality. Ideally, the selected properties should be easy to measure and the results should be reproducible (Wang *et al*., 2003). Based on the results of factor analysis and communality values, the properties that explained the greatest proportion of the total variance in the present study included sand content, SOM, TN, *WSA*, and *MWD*. These soil characteristics seem to be the suitable parameters for assessing the effects of land use pattern on soil degradation in the study region. Since SOM was highly correlated to TN, and *WSA* and *MWD* were also strongly correlated among themselves. To optimize the number of indicators, it is suggested to use SOM and *MWD* in addition to sand as the parameters for assessing the soil quality as affected by land use change.

Table 5. Effects of selected land uses on the factor scores in the 0- 30 cm soil layer depth, Golestan province, northern Iran.

Land use	Factor 1	Factor 2	Factor 3
NF	0.36 a*	-0.56 c	-1.23 c
CL	-0.45 c	0.03 b	-0.13 a
RO	0.03 b	0.14 a	-0.59 b
RC	0.02 b	0.19 a	-0.49 b

* a, b,… letter indicate significant differences (P<0.01) among treatments based on Duncan's mean test.
[a] Natural forest; [b] Cultivated Land; c Reforested with Olive, [d] Reforested with Cupressus.

Effects of Land Use Change on the Selected Soil Properties

Sand Content (Indicator of Soil Erosion)

The conversion of forest into cropland is known to deteriorate soil physical properties and making the land more susceptible to erosion since macro-aggregates are disturbed (Çelik, 2005). Soil erosion can modify soil properties by reducing soil depth, changing soil texture, and by loss of nutrients and organic matter (Foster, 2001). Loss of organic matter is expected to destabilize soil aggregates and, consequently, the finer particles are transported by erosion. Sand content is a physical parameter affected by soil erosion and, hence, can be measured and used as an indicator for evaluating soil degradation under different land use systems.

The results of ANOVA indicated that there were significant (P< 0.001) differences among the four land parcels studied (Table 6). The highest and the lowest sand contents were found in the cultivated land and natural forest, respectively. The results of the multiple comparison test (Duncan's method) confirmed that there were significant differences (P< 0.01) between mean values of sand content in the natural forest, cultivated land and land reforested with *Olea europea*. There was no significant difference in sand content between the plot of natural forest and that reforested with *Cupressus arizonica*.

The parent material of the selected site under different land uses is loess deposit containing mainly silt size particles, almost completely homogenous within the depth of the profile. Therefore, considering the short distances between the studied land parcels(shorter than 100 m), it is suggested that the variability in the particle size distribution is mainly due to the effects of the different land uses and not different parent materials.

The sites are located on steep slopes and cultivation is mainly done along the slope without implementing conservation practices. Therefore, over the last 40 years, the finer soil particles have been selectively removed by erosion, thereby increasing the proportion of the coarser particles in the soil, as also suggested by Wang *et al*. (2006). These processes have led to significant increase in the percentage of sand content (+252%) compared to the plot under natural forest on the same slopes. But, the reforestation of steep slopes during the last 30 years has reduced the loss of fine particles; consequently, the percentage increase in the sand contents were 141% and 29.5% in the land reforested by Cupressus and olive, respectively, as compared to the natural forest.

According to Ajami *et al*. (2006), clay content decreased from 38.8% to 20% in the surface horizons after deforestation and cultivation of loessial soils of the Golestan Province, northern Iran. In contrast, the percentage of sand content increased 1.5 to 2 times following deforestation and silt content also increased from 55% to 70% in the parcel under cultivation. Islam and Weil (2000a) indicated that the cultivated soils in Bangladesh were considerably lower in silt and lower in clay compared to the adjacent soils under natural forest, most likely as a result of preferential removal of silt by accelerated water erosion in the monsoon seasons.

Soil organic matter (SOM) has been reported as the most powerful indicator for assessing soil potential productivity in different regions of the world under varied land uses and managements (Shukla *et al.*, 2006; Ajami *et al*., 2006; Kiani *et al*., 2003). The results of ANOVA showed that there were significant differences among the studied land parcels (Table 6). The mean comparisons using Duncan's test indicated that there was significant (P< 0.01) difference in SOM among the four land uses studied, especially between the natural forest (6.45%) and the cultivated land (1.84%) (Table 7). Evrendilek *et al*. (2004) showed that deforestation and subsequent cultivation decreased organic matter by 48.8%. Also, other studies have shown that there were significant differences in SOM content of the soils under cultivation and mature woodland (Chidumayo and Kwibisa, 2003; Kiani *et al.*, 2003; Ajami *et al.*, 2006; Khormali *et al*., 2006).

Table 6. The result of analysis of variance (ANOVA) for selected soil properties under different land uses all treatments, Golestan province, northern Iran.

		Sum of squares	df	Mean square	*F*	*P*-value
SAND	Between groups	21876.01	3	7292	58.86	0.001
	within groups	19448.57	157	123.87		
	total	41324.58	160			
SOM[a]	Between groups	402.31	3	134.1	355.16	0.001
	within groups	59.28	157	0.37		
	total	461.6	160			
MWD[b]	Between groups	26.66	3	8.88	86.01	0.001
	within groups	16.22	157	0.1		
	total	42.89	160			

[a] Soil Organic Matter, [b] Mean Weghit Diameter.

Table 7. Comparison of mean values of selected soil parameters under different land uses using Duncan's test, Goletan province, northern Iran (Duncan's method).

		Land use			
Soil property	Unit	NF[a]	CL[b]	RO[c]	RC[d]
Sand	%	10.5c*	37.0a	25.3b	13.6c
SOM[e]	%	6.45a	1.84c	2.75b	3.17b
MWD[f]	Mm	2.42a	1.16b	2.10a	2.13a

*a, b, c, … indicate significant differences (P< 0.01) among treatments based on Duncan's mean test.
[a] Natural forest; [b] Cultivated Land; [c] Reforested with Olive; [d] Reforested with Cupressus; [e] Soil Organic Matter, [f] Mean Weghit Diameter.

In this study, deforestation and cultivation of land decreased SOM by 71.5% (Table 7). Disturbance can alter soil temperature, moisture, and aeration, and, thus, increase the decomposition rate of SOM. SOM in the forested land was higher than in the cultivated parcel, since the soil in the first case was not tilled or exposed to erosion. Probably, the loss of SOM combined with greater sand content and poorer aggregation resulted in higher bulk density (23.4% increase) under cultivation compared to the natural forest.

The continuous use of heavy farm machineries can further aggravate the loss of SOM through erosion. Similar results were reported by Hajabbasi *et al*. (1997) and Çelik (2005) who showed that deforestation and subsequent tillage practices resulted in 20.0% and 7.9% increase in bulk density of the surface soil in the central Zagros Mountain Range in Iran and southern highlands of Turkey, respectively. This is also consistent with the findings of other researchers (Vagen *et al*., 2006; Rasiah *et al*., 2004; Kiani *et al*., 2003). Organic matter is greatly influenced by the land use change on the hillslope soils with loess parent material.

In the studies by Kiani *et al*. (2003) and Ajami *et al*. (2006), it was shown that, by the conversion of land use from forest to cultivation on the loess hill-slope soils of Golestan Province, the soil organic carbon decreased, respectively, from 4% to 1.3% and from 7.2% to 1.2%, ,.Consequently, due to the significant role of SOM in soil erodibility, the K factor of the cultivated land increased by 66.7% compared to the value found for the natural forest. Çelik (2005) reported that soil erodibility factor of the cultivated soil was 2.4 times higher than that of the forest soil.

Reforestation of degraded land with *Olea europea* and *Cupressus arizonica* increased the SOM by 49.5% and 72.3%, respectively, compared to the cultivated land; and there were significant differences between the reforested and the cultivated soils (Table 7). These results are consistent with those observed for the surface soils following afforestation (Ritcher *et al.,* 1999; Paul *et al.,* 2002). Moreover, following an increase in the SOM in the land reforested by olive and Cupressus, BD decreased to 1.47 and 1.36 g cm^{-3}, respectively, (Table 2) while the soil erodibility factor (K factor) decreased by 36.1% and 33.3% compared to the cultivated fields.

Because of the abovementioned effects of SOM, natural forest soils had more TN, AWHC, and MR as compared to the cultivated soils (Table 2). Evrendilek *et al*. (2004) also suggested that cultivation decreased the total soil porosity, soil respiration rate, and nutrient-retention capacity.

The mean weight diameter (MWD) of soil aggregates was significantly (P< 0.001) different among the four land uses (Table 6). Duncan's test showed that there were significant differences (P< 0.01) between soils under natural forest (2.42 mm) and under cultivation (1.16 mm) (Table 7).

Aggregate stability depends on the interaction between primary particles and organic constituents to form stable aggregates, which are influenced by various factors related to soil environmental conditions and management practices (Elustondo *et al*., 1990). SOM plays a key role in the formation and stabilization of soil aggregates (Lu *et al*., 1998). Loss of soil organic carbon with cultivation is related to the destruction of macro-aggregates. There was a highly significant correlation (0.86) between SOM and *MWD* (Table 3).

The differences observed in the percentages of the stable aggregates under various land uses likely resulted from the differences in the quality and quantity of SOM. Caravaca *et al.* (2004) indicated that aggregate stability of cultivated soils was significantly lower (mean 40%) than that of forested soils (mean 82%). Findings of Çelik (2005) also indicated that cultivation caused 61 and 52% decrease in the *MWD* in the 0-10 cm and 10-20 cm soil layers, respectively. The higher aggregation in the forested soils might have protected SOM from decomposition by microbial activity (Çelik, 2005; Evrendilek *et al*., 2004).

Figure 3 shows the distribution of the aggregate size classes. Distribution of soil aggregates differed significantly among different land uses. The cultivated soils had significantly (P< 0.01) higher mass of aggregates in the smaller diameter classes (0.1-0.25 mm) than the other land uses. In the 2-4.6 mm class, however, the forest soils showed greater mass of aggregates than the cultivated soils. The small aggregate size was found to be a useful indicator of soil degradation. Reforestation with olive and Cupressus in the study area increased the proportion of larger aggregates and reduced those of smaller ones significantly.

CONCLUSIONS

The physical, chemical, and biological characteristics of soils under four land uses were measured and suitable soil quality indicators were selected using factor analysis. The first three factors explained about 76% of the total variance. Communality estimates for these three factors and correlation studies

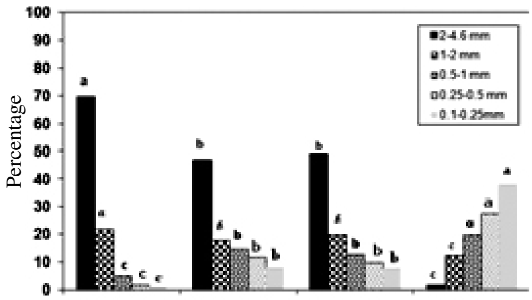

Figure 3. Mean comparisons of different classes of aggregates in four land uses (NF: Natural forest, RC: Reforested with Cupressus; RO: Reforested with Olive, CL: Cultivated land) (a, b, c, …letters indicate significant differences among treatments based on Duncan's mean test, the treatments with the same letter are not significantly different at P< 0.05)

showed that the most suitable indicators were *MWD*, SOM, and sand content to evaluate soil quality following land use change. The clearing and cultivation of forest lands resulted in the degradation of soil properties compared to the soils under well-stocked natural forest, Olea *europea* and *Cupressus arizonica* reforestation. SOM and *MWD* size were reduced and sand content (as indicator of soil erosion) was increased. Reforestation with Olea *europea* and *Cupressus arizonica* indicated that planting of well-adapted and fast-growing trees can gradually improve the soil quality and rehabilitate the degraded lands. Therefore, greater attention is needed to conserve the soils on the hilly slopes by preventing deforestation and through reclamation of degraded land by establishing appropriate forest and orchard plantations.

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ارزیابی اثر تغییر کاربری اراضی روی شاخص های کیفیت در خاکهای لسی استان گلستان، ایران

ش. ایوبی، ف. خرمالی، ک. ل. ساهراوات، و ا. س. رودریگز دلیما

چکیده

این مطالعه به منظور ارزیابی اثر تغییر کاربری اراضی روی شاخص های کیفیت خاک به کمک تکنیک تجزیه فاکتورها در اراضی تپه ماهوری منطقه شصت کلای استان گلستان انجام شده است. به این منظور ۴۰ نمونه خاک از افق سطحی (۳۰-۰ سانتی متر) از چهار کاربری شامل (۱) جنگل طبیعی، (۲) اراضی کشت شده، (۳) اراضی جنگل کاری شده با زیتون و (۴) اراضی جنگل کاری شده با سرو (جمعاً ۱۶۰ نمونه) برداشت گردید. چهارده تجزیه فیزیکی، شیمیایی و بیولوژیکی روی نمونه های خاک به روشهای استاندارد آزمایشگاهی صورت پذیرفت. نتایج تجزیه فاکتورها نشان داد که میانگین وزنی قطر خاکدانه ها (MWD)، درصد خاکدانه های پایدار در آب (WSA)، مقدار ماده آلی خاک (SOM) و ازت کل (TN) بهترین شاخص های ارزیابی کیفیت خاک در منطقه مورد مطالعه برای نشان دادن اثر تغییر کاربری اراضی بودند. نتایج آنالیز واریانس و مقایسه میانگین ها نشان داد که در سطح احتمال ۹۹ درصد بین چهار تیمار مورد بررسی بین MWD , SOM و مقدار شن اختلاف معنی داری وجود دارد. قطع کامل درختان طبیعی منطقه و کشت و کار در ۴۰ سال گذشته منجر به کاهش ۷۱/۵٪ ماده آلی شده است. کشت و کار باعث کاهش ۵۲/۱٪ مقدار MWD، و باعث افزایش ۲۵۲٪ مقدار شن شده است. جنگل کاری مجدد اراضی تخریب شده با زیتون و سرو به ترتیب باعث افزایش ۴۹/۵٪ و ۷۲/۳٪ مقدار ماده آلی در مقایسه با اراضی زراعی گردیده است. همچنین مقدار MWD در اراضی کشت شده با زیتون و سرو به ترتیب ۸۱ و ۸۳/۶ درصد نسبت به اراضی زراعی افزایش یافته است. نتایج کلی این تحقیق نشان داد که قطع کامل جنگل و به تبع آن کشت و کار ممتد روی اراضی تپه ماهوری لسی باعث کاهش کیفیت خاک شده است در حالیکه جنگل کاری مجدد این اراضی کیفیت خاک را بهبود بخشیده است.

[DOR: 20.1001.1.16807073.2011.13.5.13.4]