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Micromorphology and Quality Attributes of the Loess Derived Soils Affected by Land Use Change: A Case Study in Ghapan Watershed, Northern Iran

Farhad Khormali* **and Somaye Shamsi**

Dept. of Soil Science, College of Agriculture, Gorgan University of Agricultural Sciences and Natural Resources, Gorgan, Iran

**Corresponding author, e-mail: Khormali@yahoo.com, fkhormali@gau.ac.ir; Fax: +98 171 4426813; Tel: +98 171 4426523*

Abstract: In order to study the effects of different land vegetative covers on soil quality attributes, a loess hill slope was selected in eastern Golestan Province, Ghapan watershed, Iran. Four profiles in four land uses, including *Quercus* natural forest; *Pinus* artificial forest; *Cupressus* artificial forest and a cultivated land, were studied. Results showed that MWD was significantly different in the studied land uses, and it varied between 1.6 mm in *Quercus* natural forest and 0.31 mm in cultivated land use. The lowest CEC, microbial respiration rate and organic carbon were 28.4 cmol·kg^{-1}, 177 μgCO$_2$·g^{-1}·day^{-1} and 1.32 % found in cultivated land use, respectively.

The organic matter content in the forest areas was considerably higher than that of cultivated land use. The studies on soil profile development revealed that the natural forest soils were highly developed. The soils of the *Quercus* natural forest were classified as Calcic Haploxeralfs with a well developed argillic horizon unlike the cultivated soils which showed the minimum development and classified as Typic Xerorthents. The soils of the artificial forests had both mollic epipedons and were classified as Typic Calcixerolls with moderate profile development. Micromorphological studies revealed that argillic horizons had speckled and partly crystallitic b-fabric in the natural forest indicating the high landscape stability. In contrast, the crystallitic b-fabric of other land uses shows the absence of enough leaching of carbonate and the subsequent migration of clay particles indicating the unstable conditions and high soil erosion. Intense erosion of the surface horizons of cultivated land use has resulted in the outcropping of the subsurface carbonate rich horizons preventing soil development.

Keywords: Soil micromorphology; soil quality; loess; Iran

Introduction

Deforestation is believed to diminish soil quality and lead to a permanent degradation of land productivity. Larson and Pierce (1991) defined soil quality as the capacity of a soil to function within the ecosystem boundaries and to interact positively with surrounding ecosystems. Two of the most important factors associated with the soil quality concept are: (1) soil has both inherent and dynamic properties; and (2) soil quality assessment must reflect biological, chemical, and physical properties (Karlen et al. 2003), including aggregate stability, organic matter content, soil depth, water holding capacity, changes in pH values and microbial respiration rate, which changed with different land vegetations. Destruction of vegetative covers and conversion to agriculture deteriorate the natural ecosystem and diminished soil quality (Islam and Weil 2000). Researches showed that the changes that mainly occur after subsequent cropping results in a decrease in soil organic matter, plant available nutrients, microbial respiration, and an increase in bulk density. Nowadays, the changes of forests and pastures to agriculture are one of the important problems in environmental destruction (Wali et al. 1999). Soil micromorphology is important to demonstrate the

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effect of vegetative cover on destruction of soil quality. Micromorphlogy is considered as a method for studying the undisturbed soil samples with the aid of microscopic and ultramicroscopic techniques in order to identify their different constituents and determine their mutual relations, in space and time (Stoops 2003). Its aim is to search for the processes responsible for the formation or transformation of the soil in general, or of specific features, as well as natural (e.g., clay skins, nodules) and artificial (e.g., irrigation crusts, plow pans).

The main objectives of this study were to investigate soil quality attributes and soil development, and to evaluate role of land use change and vegetative cover on destruction of soil quality in eastern Golestan province, Ghapan area.

1 Methods and Material

1.1 Description of the study area

The study area is located at Ghapan watershed, Province of Golestan, North of Iran (Figure 1). The mean annual temperature and precipitation there are 15.9°C and 535 mm, respectively. The soil moisture and temperature regimes are xeric and thermic, respectively. Four profiles in four land uses, including *Quercus* natural forest, *Pinus* artificial forest, *Cupressus* artificial forest and a cultivated land, were dug, described and classified according to the Soil Survey Manual (Soil Survey Staff 1993) and Keys to Soil Taxonomy (Soil Survey Staff 2006). The major parts of the study area are occupied by the parent material mainly composed of loess deposits.

1.2 Soil sampling and analyses

The different horizons were sampled and the physico-chemical analyses were carried out in laboratory. The soil samples were oven-dried at 105°C for 24 h and weighed to estimate bulk density (Blake and Hartage 1986) using paraffin method. Particle size distribution and soil texture were 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 in diameter. The method of Kemper and Rosenau (1986) was used to determine MWD.

PH was measured in saturated paste using pH electrode (Mclean 1982) and electrical conductivity (EC) was measured in the extract using conductivity meter (Rhoades 1982). Soil organic

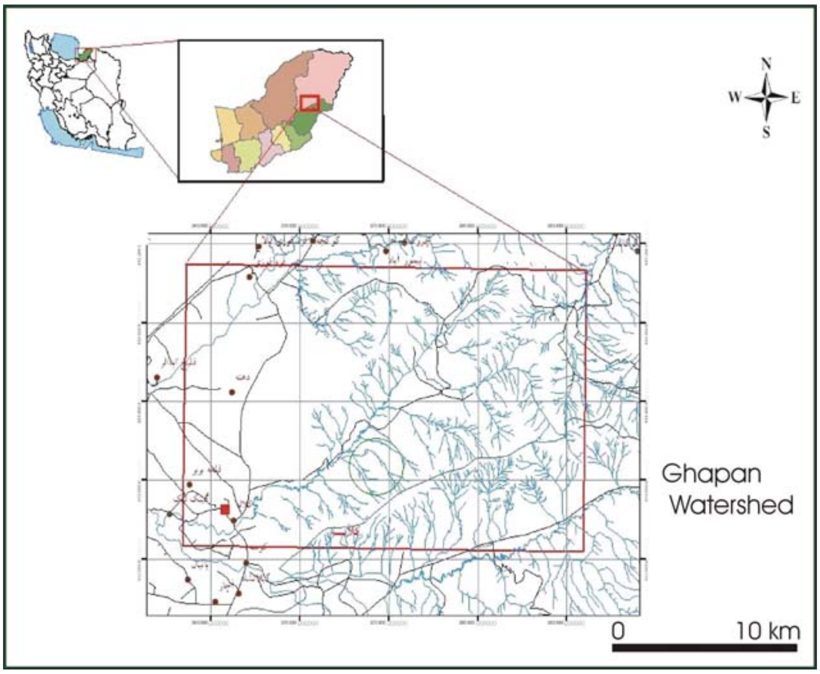

Figure 1 Location map of the study area

carbon (SOC) was determined using a wet combustion method (Nelson and Sommers 1982). Equivalent calcium carbonate was determined by titration with acid. Cation exchange capacity (CEC) was determined using sodium acetate (NaOAc) at a pH 8.2 (Chapman 1965). Microbial respiration rate (MR) was measured by the closed bottle method of Stotzky (1965). One-way analysis of variance (ANOVA) and mean comparison using Duncan's test were conducted with SPSS software.

1.3 Micromorphological analyses

The thin sections of about 80 and 40 cm^2 were prepared from air-dried undisturbed and oriented clods using standard techniques described by Murphy (1986). Micromorphological descriptions were made according to Stoops (2003).

2 Results and Discussion

2.1 Genesis and morphological properties

The soils of the artificial forests had mollic epipedon and were classified as Typic Calcixerolls with moderate development (Tables 1 and 2). Most of the *Quercus* natural forest soils were mainly classified as Calcic Haploxeralfs with the well developed argillic horizons. In the natural forest land use clay illuviation and formation of argillic horizon has occurred mainly through the dissolution and downward migration of carbonates and the subsequent clay dispersion and movement, which is in line with the finding of Khormali, et al. (2003). The cultivated soils showed the minimum development and were classified as Typic Xerorthents. Almost no sign of carbonate leaching and clay illuviation has been detected in this land use.

2.2 Chemical soil quality indicators

2.2.1 Soil pH

The pH values of the natural forest and cultivated soils varied significantly. In general, the pH values of forest soils were lower than those of the cultivated soils, especially in the surface layers. The average pH in the soil increased from 6.5 in forest to 7.4 in the cultivated (Table 2). The average pH in the *Pinus* artificial forest and *Quercus* artificial forest soils was about 7.2. Leaching of basic cations in the forests and CO_2 released by microbial respiration are the main reasons for the lower soil pH of forest (NRCS 1999). In contrast, the lower downward leaching of ions occurred in the cultivated land use. Tillage practices which redistributed these leached ions in surface layers were responsible for higher pH in these soils.

2.2.2 Soil organic carbon

Soil organic carbon (SOC) is one of most the important soil quality indicators to evaluate the effects of management practices in the forest and cultivated land uses (Pathak et al. 2004). The knowledge of SOC in terms of its amount and quality is essential to sustain the quality and productivity of soils (Velayutham et al. 2000). Potentially large carbon stocks can be stored in soils as organic matter but this is affected greatly by land use (Lal 1999). The results of this study showed that SOC was different in the studied land use soils and varied between 5.7 % in the *Quercus* natural forest and 1.32 % in cultivated land use (Table 2). Nardi, et al. (1996) believed that the rupture of the larger aggregates to the smaller ones following tillage practice aggravated the loss of soil organic matter. The coarser texture followed by tillage machinery increased the risk of organic matter decomposition.

2.2.3 Soil calcium carbonate (CCE)

Loess material contain high amount of Carbonate. Land use change has resulted in the significant change in CCE (Table 2, Figure 2). The higher moisture availability along with CO_2 released from microbial respiration help downward leaching of carbonate and its subsequent accumulation in the Bk horizons. Khormali et al., (2006) introduced the variety of complex processes accounting for the CCE dynamics in soil. In the higher available soil moisture and higher pCO_2, lithogenic carbonate is dissolved and migrates downward. CCE in forest is significantly lower than cultivated land, indicating the stability of forest landscape to allow the downward leaching (decalcification) and subsequent accumulation and precipitation (recalcification) processes.

Table 1 Soil morphological properties in different land uses

Land use	Horizon	Depth cm	Color moist	Texture	Structure	Consistence	Reaction
Quercuse natural forest	A	0-12	10YR 3/2	CL	1fgr	vfr	no
	Bt1	12-30	10YR4/4	CL	1fgr	vfr	no
	Bt2	30-54	10YR4/4	L	2mabk	vfr	no
	Bk	54-150	10YR5/4	CL	1fabk	vfr	+
Pinus artificial forest	A	0-18	10YR 3/2	SiCL	1fgr	vfr	+
	Bw	18-49	10YR 4/6	SiL	1fsbk	vfr	+
	Bk	49-75	10YR6/6	CL	1fsbk	vfr	++
Qupresus artificial forest	A	0-15	10YR 2/3	SiL	2mgr	vfr	no
	Bw	15-35	10YR 3/3	L	2msbk	vfr	+
	Bk	35-150	10YR 4/6	CL	2fsbk	fr	++
Cultivated land	A	0-20	10YR 4/6	SiL	1fsbk	vfr	+
	Bk	20-50	10YR 4/6	SiL	1fsbk	vfr	+
	C	50-150	10YR 5/6	SiL	m	fr	+

Table 2 Soil physico-chemical properties in different land uses

Land use	Horizon	pH	MWD mm	OC %	Lime %	CEC $\text{Cmol}\cdot \text{kg}^{-1}$	C %	Si %	S %	BD $\text{g}\cdot\text{cm}^{-3}$	Microbial respiration $\mu\text{gCO}_2\cdot\text{g}^{-1}\cdot\text{day}^{-1}$
Fine, mixed, superactive, thermic, Calcic Haploxeralfs											
Quercuse natural forest	A	6.5	1.6	4.52	9.5	30.8	29	38	33	1.89	342
	Bt1	6.4	0.55	0.30	21.5	26.3	38	23	39	1.72	317
	Bt2	6.8	0.79	0.27	20	36.4	35	26	39	1.44	245
	Bk	7.3	0.49	0.42	43	34.7	23	39	38	1.4	244
Fine-loamy, mixed, superactive, thermic, Typic Calcixerolls											
Pinus artificial forest	A	7	0.89	2.61	34.5	39.2	32	50	18	1.24	239
	Bw	7.3	1.07	1.09	18.5	27.1	21	60	19	1.37	234
	Bk	7.2	0.58	0.39	31.5	22.6	23	42	35	1.46	223
Fine-loamy, mixed, superactive, thermic, Typic Calcixerolls											
Qupresus artificial forest	A	7.2	1.47	5.7	6.5	44.2	11	80	9	1.4	261
	Bw	7.2	1.33	1.95	27.5	36.9	26	41	33	1.44	252
	Bk	7.8	1.22	0.33	45	34.1	26	62	12	1.4	250
Fine-silty, mixed, superactive, calcareous,Typic Xerorthents											
Cultivated land	A	7.4	0.31	1.32	30	28.4	26	56	18	1.4	177
	Bk	7.5	0.30	0.7	45	26	26	59	15	1.5	140
	C	7.3	0.44	0.31	65	22.4	27	61	12	1.33	106

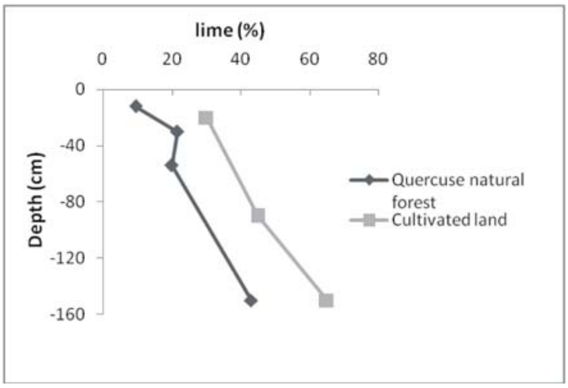

Figure 2 Depth distribution of calcium carbonate in the natural forest and cultivated land

2.2.4 Cation exchange capacity (CEC)

The cation exchange capacity (CEC) of the soil is determined by the amount of clay and/or humus that is present. The CEC variation in forest and cultivated land uses to the 1 m depth varied due to tillage practices and decreased significantly in all the depths of cultivated compared to forest (Table 2). The CEC decreased in the soil from 44.2 cmol·kg^{-1} in forest to 28.4 cmol·kg^{-1} in the cultivated land. The results are in accordance with the findings of Vagen et al., (2006). The reduction of CEC in cultivated land is largely due to the loss of SOM and the clay content. This reduction is higher for the surface soil layer.

In general forest soil CEC values were higher than cultivated soils. This reveals that the depletion of organic matter as a result of cultivation has reduced the CEC values under the cultivated lands.

2.3 Biological soil quality indicators

Biological parameters are relatively dynamic and sensitive to change, so they can be used as indicators of soil quality at an early stage (Pathak et al. 2004). Population of micro-, meso-, and macro-organisms, soil respiration, enzyme activities, rate of nutrient mineralization, and microbial biomass are some biological soil quality indicators. Analysis showed that soil respiration values were statistically significant between natural forest and cultivated soils (Table 2). High amount of respiration in forest may be due to high new organic matter that is annually added to soil surface (Kiani et al. 2004). Loss of organic matter in the cultivated area as a result of tillage practices and inappropriate management have caused lower respiration. The microbial respiration rate in *Quercus* natural forest, Pinus artificial forest, *Cupressus* artificial forest and cultivated land, were 342, 261, 239 and 177 μgCO$_2$·g^{-1}·day^{-1}, respectively.

2.4 Physical soil quality indicators

2.4.1 Soil texture

Soil texture changed significantly due to 50 years of cultivation from silty clay loam in forest to silt loam in cultivated land. The most significant change occurred in the clay fraction with 33.25 %

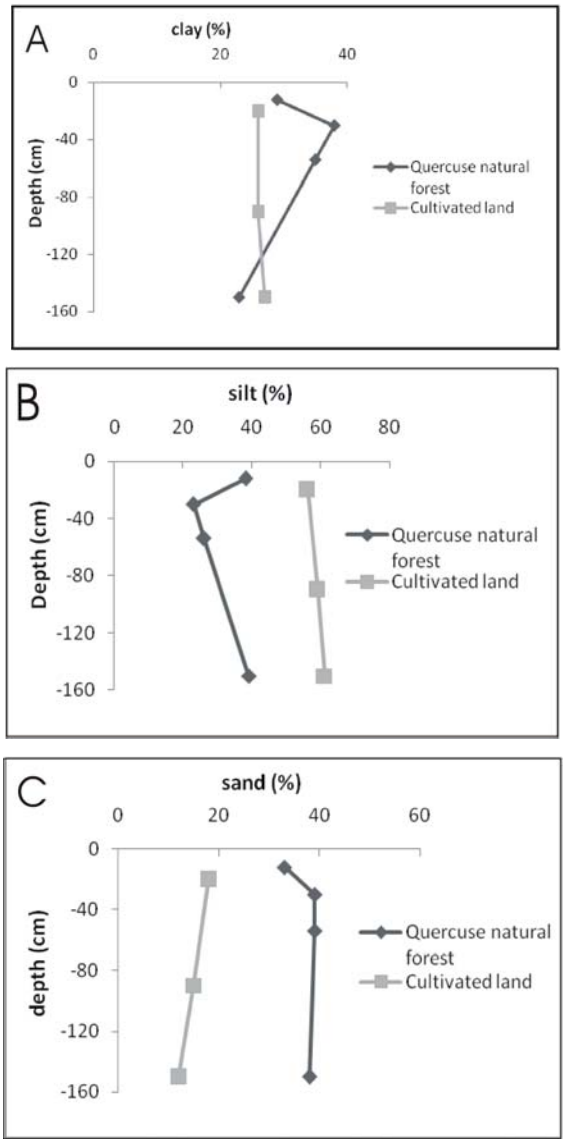

Figure 3 Depth distribution of clay (A), silt (B) and sand (C) in the natural forest and cultivated land

in forest to 26 % in cultivated land. The silt content increased from 31.5 % in forest to 58.5 % in cultivated (Table 2, Figure 3). Hajabbasi et al., (1997) reported lower clay content in cultivated areas than the adjacent forest due to organic matter decomposition and the subsequent disintegration of the aggregates and loss of the finer particles in the cultivated land.

2.4.2 Soil aggregate stability

Mean weight diameter (MWD) of the soils showed that tillage practices resulted in the significant decrease in aggregate stability. Results showed that MWD was significantly different in the studied land uses and varied between 1.6mm in *Quercus* natural forest and 0.31 mm in cultivated land use (Figure 4). This is in accordance with the findings of Hajabbasi et al., (1997), Caravaca et al. (2004), Evrendilek et al., (2004) and Celik (2005). Tillage practices disintegrate the larger aggregates and result in higher loss of organic matter (Nardi et al. 1996, Shepherd et al. 2001). Severe losses of SOM, increased silt content, decreased microbial activity of heavy machinery were the main responsible factors for the decreased MWD following tillage practices. The lowest MWD was found in the cultivated land use on which the tillage and agricultural activity was intensive and therefore a showed significant difference with other land uses (Table 2).

2.5 Micromorphological Studies

Micromorplological techniques can help study the soil formation processes and also soil quality attributes under different managements. The main micromorphological features to study are: soil organic matter distribution and content, porosity, soil microstructure, etc. Micromorphological investigations revealed that the natural forest soils had strong granular and crumb microstructure (Table 3). Presence of this structure in soils is relevant by biological activity (Stoops 2003). In contrast, soil surface microstructure of the cultivated area is massive, indicating to compact and deterioration of natural structure. Observation of planes in depth of cultivated land could be due to soil compaction. Deterioration of natural covering of land cause loss of surface soil and the lack of time for pedogenic processes for development of soil in cultivated land. In contrast, artificial forest land use have granular microstructure and mollic horizons (Figure 5).

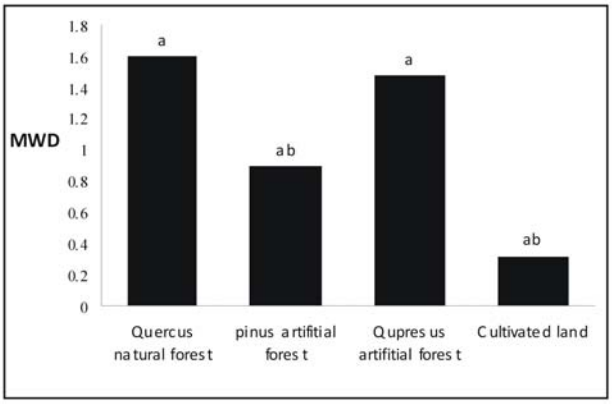

Figure 4 Comparison of the MWD (mm) in the studied land uses

Speckled b-fabric of the argillic horizon and the crystallitic b-fabric of the underlying calcic horizon indicate that the natural forest land had high stability allowing the downward leaching and decalcification of the upper horizons and subsequent clay movement (Figure 6). Presence of carbonate coating in the lower horizons indicates to the precipitation of carbonate.

Formation of mollic epipedon in the natural forest land use also indicates high accumulation of organic matter in the surface soil. Presence of calcic horizons in artificial forest soils were mainly related to decalcification and its downwards leaching and precipitation in the lower horizons that causes formation of crystallitic b-fabric.

3 Conclusion

Deforestation and cultivation on the loess hillslopes has resulted in the deterioration of soil quality as described by different physical, chemical, biological and micromorphological indicators. Preservation of SOM in the cultivated areas through incorporation of plant residues, replantation of artificial forest in the sloping areas, especially in the shoulder and backslope positions, can reduce the deterioration of soil quality and also soil erosion.

Table 3 Soil micromorphological properties in different land uses

Land use	Horizon	Voids-microstructure	c/f related distribution	b-fabric	Pedofeatures
Quercuse natural forest	A	Channel-granular	Single-spaced porphyric	Speckled	Excrements of the soil fauna
	Bt1	Channel-Well separated subangular blocky	Double-spaced porphyric	Speckled (50 %)-Crystallitic (50 %)	Clay coatings
	Bt2	Channel-moderately separated subangular blocky	Double-spaced porphyric	Speckled (50 %)-Crystallitic (50 %)	Clay coatings
	Bk	Channel-moderately separated subangular blocky	Single-spaced porphyric	Crystallitic (70 %)-Speckled (30 %)	Carbonate coating-Geodic nodule-Cytomorphic calcite
Pinus artificial forest	A	Channel-granular	Single-spaced porphyric	Speckled	Excrements of the soil fauna
	Bw	Channel-massive	Close porphyric	Crystallitic	-
	Bk	Vughs, Channel-Weakly separated subangular blocky	Close porphyric	Speckled (50 %)-Crystallitic (50 %)	Calcite Nodules-Cytomorphic calcite
Qupresus artificial forest	A	Channel-granular	Single-spaced porphyric	Speckled	Excrements of the soil fauna
	Bw	Channel-massive	Close porphyric	Crystallitic	-
	Bk	Channel-Weakly separated subangular blocky	Close porphyric	Crystallitic	Cytomorphic calcite
Cultivated land	A	Channel-massive	Porphyric	Speckled (50 %)-Crystallitic (50 %)	Carbonate coating
	C	Plane-subangular blocky	Porphyric	Crystallitic	Carbonate coating

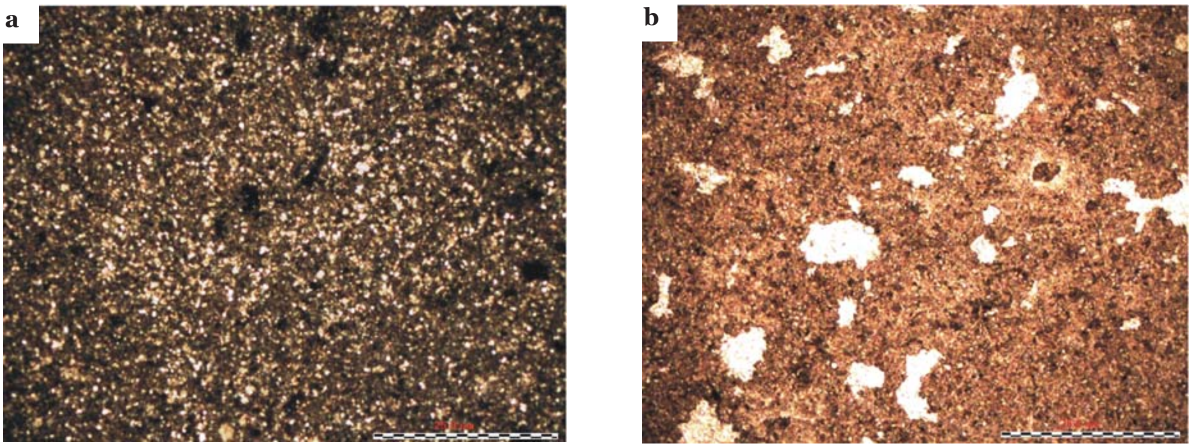

Figure 5 Massive (a, xpl) and granular (b, ppl) microstructure of the cultivated and natural forest land uses

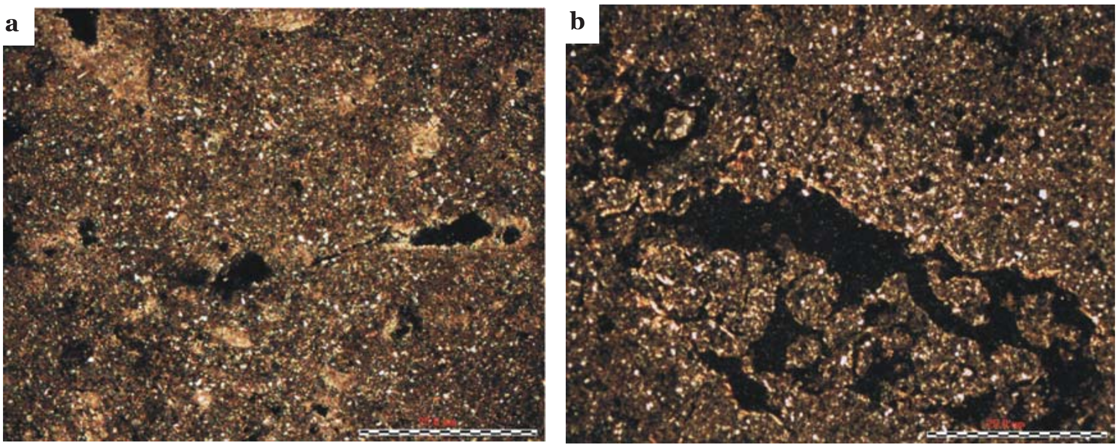

Figure 6 Crystallitic (a) and speckled (b) b-fabric of the cultivated and natural forest landuses (xpl)

References

Angers, D.A., and Mehuys, G.R., 1993. Aggregate stability to water. In: Carter, M.R., (ed.), Soil Sampling and Methods of Analysis. Lewis Pub. Boca Raton. Pp: 651-657.

Blake, G.R., and Hartage, K.H., 1986. Bulk density. In: Klute, A. (ed.), Methods of soil analysis. Part 1, Physical and mineralogical methods. 2nd ed. Agronomy. 9. Pp. 363-382.

Caravaca, F., A. Lax, and J. Albaladejo. 2004. Aggregate stability and carbon characteristics of particle-size fractions in cultivated and forested soils of semiarid Spain. Soil & Tillage Research **78**: 83–90.

Celik, I. 2005. Land-use effects on organic matter and physical properties of soil in a southern Mediterranean highland of Turkey. Soil & Tillage Research **83**: 270–277.

Chapman, H. D. 1965. Cation exchange capacity. In: Methods of Soil Analysis. Part 2. Black, C. A. (ed.). American Society of Agronomy, Madison, Wisconsin, USA.

Evrendilek, F., I. Celik and S. Kilic. 2004. Changes in soil organic carbon and other physical soil properties along adjacent Mediterranean forest, grassland, and cropland ecosystems in Turkey. Journal of Arid Environments **59**: 743–752.

Gee, G.W., Bauder, J.W., 1986. Particle-size analysis. In: Klute, A. (Ed.), Methods of Soil Analysis. Part 1, Physical and mineralogical methods. 2nded. Agronomy. 9. Pp. 383-411.

Hajabbasi, M. A., A. Jalalian and H. R. Karimzadeh. 1997. Deforestation effects on soil physical and chemical properties, Lordegan, Iran. Plant and Soil **190**: 301-308.

Islam, K. R. and R. R. Weil. 2000. Land use effects on soil quality in a tropical forest ecosystem of Bangladesh. Agriculture, Ecosystems and Environment **79**: 9–16.

Kemper, W.D., Rosenau, R.C., 1986. Aggregate stability and size distribution. In: Klute, A. (Ed.), Methods of Soil Analysis. Part I: Physical Analysis. SSSA. Madison, WI, pp. 425-442.

Khormali, F., A. Abtahi, S. Mahmoodi and G. Stoops. 2003. Argillic horizon development in calcareous soils of arid and semiarid regions of southern Iran. Catena **53**: 273-301.

Khormali, F., A. Abtahi and G. Stoops. 2006. Micromorphology of calcitic features in highly calcareous soils of Fars Province, Southern Iran. Geoderma **132**: 31-46.

Murphy, C.P., 1986. Thin Section Preparation of Soils and Sediments. A&B Academic Publ., Berkhamsted.

Nardi, S., G. Cocheri and G. Dell' Agnola. 1996. Biological activity of humus. In: Piccolo, A. (Ed.), Humic Substances in Terrestrial Ecosystems. Elsevier, Amsterdam. Pp. 361–406.

Natural Resources Conservation Service (NRCS), USDA. 1996. Soil Quality Information Sheet. Indicators for Soil Quality Evaluation.

Natural Resources Conservation Service (NRCS), USDA. 1998. Soil Quality Information Sheet. Soil Quality Indicators.

Natural Resources Conservation Service (NRCS), USDA. 1999. Liming To Improve Soil Quality in Acid Soils. Soil Quality–Agronomy Technical Note, No. 8.

Nelson, R. E. 1982. Carbonate and gypsum. In: Methods of Soil Analysis. Part II. Page, A. L. (Ed.). American Society of Agronomy, Madison, Wisconsin, USA.

Pathak, P., K. L. Sahrawat, T. J. Rego and S. P. Wani. 2004. Measurable Biophysical Indicators for Impact Assessment: Changes in Soil Quality. In: Shiferaw, B., H. A. Freeman and S. M. Swinton (Eds.), Natural resource management in agriculture. Methods for assessing economic and environmental impacts. ICRISAT, Patancheru, India.

Rhoades, J.D. 1982. Soluble salts. In: Page, A.L. (ed.), Methods of Soil Analysis, Part II, 2nd Edition, ASA, Monograph, No.9, Madison, WI. Pp. 167-179.

Shepherd, T. G., R. H. Saggar Newman, C. W. Ross and J. L. Dando. 2001. Tillage induced changes in soil structure and soil organic matter fractions. Aust. J. Soil Res. 39: 465–489. Stoops, G. 2003. Guidelines for analysis and description of soil and regolith thin sections. SSSA. Inc. Madison, Winsconsin.

Stoops, G. 2003. Guidelines for analysis and description of soil and regolith thin sections. SSSA. Inc. Madison, Winsconsin.

Stotzky, G. 1965. Microbial respiration. In: Black, C.A. (ed.). Methods of soil analysis, part 2. Am. Soc. of Agron: 1550-1572.Inc, Madison, Wis.

Soil Survey Staff, 1993, Soil Survey Manual. USDA, Handbook No. 18. Washington, DC.

Soil Survey Staff, 2003, Keys to Soil Taxonomy. USDA, NRCS.

Vagen, T. G., M. A. A. Andrianorofanomezana, and S. Andrianorofanomezana. 2006. Deforestation and cultivation effects on characteristics of Oxisols in the highlands of Madagascar. Geoderma **131**: 190-200.

Wali, M. K., F. Evrendilek, T. West, S. Watts, D. Pant, H. Gibbs and B. McClead. 1999. Assessing terrestrial ecosystem sustainability usefulness of regional carbon and nitrogen models. Natur. Resour. **35**: 20–33.

Velayutham, M. 2000. Organic carbon stock in soil of India. Global climate change and tropical acosystem **28**:71-95.