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Effect of Land Use Change on Soil Properties and Clay Mineralogy of Forest Soils Developed in the Caspian Sea Region of Iran

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ABSTRACT

All of the tea plantations in Iran are concentrated in the Caspian Sea region on soils previously developed under deciduous natural forests. This research conducted to study the effect of land use change (from forest to tea) on selected physico-chemical and mineralogical properties of soils under humid climate and mountainous landscape in Northern Iran. Three transects facing west to northwest in both tea plantation and the nearby natural forest were selected. A total of 18 soil profiles formed on different physiographic positions i.e. summit, shoulder and foot slope were studied and morphological features of the soils were described. Soil samples taken from each horizon were analyzed. A two factor completely randomized design was used to take soil samples from surface horizons in each transect. Results showed that after changing forest to tea cultivation pH, cation exchange capacity, clay content and the amount of organic carbon of the soils were decreased at $P< 0.01$ significance level, but bulk density was increased compared to soils under natural forest. X-ray diffractograms of clay fractions showed that vermiculite, vermiculite–illite mixed layers and hydroxy interlayered clay minerals were the major clay components. Soils under tea cultivation possessed highly developed and more prominent argillic horizons and contained more clay fraction in the lower horizons in all physiographic positions.

Keywords: Forest soils, Land use change, Soils of Iran, Tea cultivation.

INTRODUCTION

Land use changes such as conversion of forest to cultivated land significantly influence soil properties and modify soil forming processes. Land use changes can drastically affect the soil environment, which in turn markedly influences soils and soil processes (Chen *et al.,* 2000). Smith *et al.* (2002) reported that in Brazil, conversion from native Amazonian forest to plantation forests altered the amount of soil organic carbon (SOC). Furthermore, land use change can also alter the chemical nature of soil organic C (Quideau *et al.,* 2000). Several scientists reported that soil aggregate size distribution and stability were important indicators of soil physical quality which reflect the impact of land use and soil management (Castro Filho *et al.,* 2002). Conversion of forest to other land uses could result in higher bulk density, lower hydraulic conductivity, and higher susceptibility to soil erosion, thereby exacerbating soil degradation and decline in SOC concentration (Lal, 2003). Tillage operations disrupt soil structure and accelerate SOC oxidation by increasing aeration, which in turn stimulates microbial activity (Vance, 2000). In contrast, conservation tillage or no till cultivation have less deleterious effects

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on soil structure and maintain or increase SOC concentration (Blanco-Canqui and Lal, 2008). Many soils in the humid temperate regions contain large amounts of partially interlayered 2:1 clay minerals. The interlayer space of clay minerals is partially occupied by Al and Fe hydroxide polymers (Jackson, 1963). These minerals are formed when basic polymeric aluminum or iron are adsorbed in the interlayered space of 2:1 expansible clay minerals (Pai *et al.,* 2004). Topography which affects drainage water is one of critical factors in the development of different soils within a given locality (Pai *et al.,* 2007). Takyu *et al.* (2002) reported that total soil C and N were decreased at the lower slope in a tropical mountain forest. Tsui *et al.* (2004) studied three slope positions - summit, back slope and foot slope - each with a different vegetative cover. The results indicated that organic carbon content, available N and K, extractable Fe and exchangeable Na were the highest in the summit soils. The main objective of this study was to examine the effect of topography and the conversion of forest to tea cultivation on some physico-chemical characteristics and clay mineralogy of soils in the Caspian Sea region of Iran.

MATERIALS AND METHODS

Lahijan region located in northern Iran, southern coast of Caspian Sea is the major tea producing area of Iran. Tea is mainly cultivated on undulating soils and hilly land forms under temperate condition. The study area was located in Bijar Bagh, 7 km south - east from Lahijan, lying between 37° 10´ 50" northern latitude and 27.4° 3´ 50" eastern longitude. The climate of the region is humid with the mean annual precipitation of 1,312 mm and the mean minimum and maximum annual temperatures of 2.8° and 19.5°C, respectively. The mean annual humidity is 77.5% and the mean annual potential evapotranspiration is 884 mm. The soil moisture and temperature regimes are udic and thermic, respectively. The major geological formations are composed of thick sedimentary and metamorphic rocks of Tertiary and Quaternary periods. The coastal plain lying between Alborz mountain ranges and Caspian Sea consists of Marine River and Aeolian deposits of varying thicknesses (Figure 1).

After field observation, three transects covering both natural forest and tea plantation facing west to northwest were selected. 18 soil profiles located on summit, shoulder and foot slope were selected and each soil horizon was described. Soil samples were taken from various horizons of the soils studied. The summit had a linear slope of approximately 2 percent. The shoulder had a slope of approximately 18 percent and the foot slope had a convex slope of about 14 percent. Laboratory analyses were carried out on soil samples taken from selected horizons. In each transect, one plot with an area of about 50 m^2 (in a given slope and aspect) was selected and soil samples were collected from surface horizons for physico-chemical analyses. A tow factor completely randomized block design with two factors (forest and tea plantation) was used to test and compare the physical and chemical properties of the soil surface horizons. The SAS Program and the Tukey's test method were used to compare the means at 5 and 1% significance levels.

The soil samples were air dried and crushed to pass through a 2 mm sieve. Particle size distribution was determined by the pipette method (Gee and Bauder, 1986).

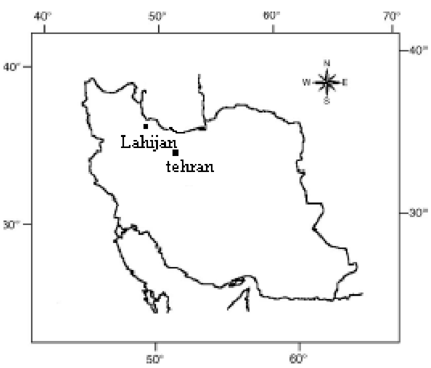

Figure 1. Location of study of area in Guilan and in Iran.

Bulk density was determined by the clod method (Klute and Dirksen, 1986). Organic carbon was measured by wet oxidation with chromic acid and back titration with ferrous ammonium sulphate (Nelson, 1982). Soil pH was measured at a soil to $CaCl_2$ ratio of 1:2 (Salinity Laboratory Staff, 1954). Cation exchange capacity (CEC) was determined using sodium acetate (NaOAc) at a pH of 8.2 (Chapman, 1965). Basic cations were determined using ammonium acetate at a pH of 7 (Salinity Laboratory Staff, 1954). The available P was measured by sodium-bicarbonate extraction according to the Olsen Method (Olsen, 1953). The total soil nitrogen content was measured by Kjeldahl method (Bremner and Mulvaney, 1982). Free Fe oxides (Fe_d) were extracted by bicarbonate–citrate-dithionite (BCD) (Mehra and Jackson, 1960). For clay mineralogical identification, the clay fraction was separated by wet sieving, gravity sedimentation method (Jackson, 1979). Samples were pretreated with 10% H_2O_2 on a hot plate to remove most of the organic matter. Clay samples were saturated with Mg and K cations and mounted as slurries on glass slides for X-ray diffraction (XRD) analysis. The air-dried Mg-saturated samples were analyzed at 25°C followed by glycerol solvation. The air-dried K-saturated samples were analyzed at 25°C and then heated at 300 and 550°C. All X-ray diffractograms were recorded with a Siemens D5000X-ray diffractometer equipped with CuKα radiation generated at 30 kV and 30 mA. The XRD patterns were recorded from 2 to 30° 2θ at a scanning speed of 2° 2θ min^{-1}.

RESULTS AND DISCUSSION

Soil Physico-chemical Properties and Development

All soils were acidic and their pH increased with depth due to extensive leaching and removal of basic cations from the upper horizons. Organic carbon was the highest in the surface layers and decreased regularly with depth. The soil texture ranged from sandy loam, sandy clay loam to clay. The soils were well drained in all physiographic positions except in the foot slopes.

Tables 1 and 2 show physical and chemical properties of the soils studied. Significant differences were observed among forest and tea soils for most of the soil properties (Table 3). The available K at the surface horizons of the soils under tea cultivation was very low due to the lack of K-fertilizer application in the soils as well as higher soil weathering and leaching process. However, the available K content of the soils under forest was significantly higher. Lower amount of available K at the surface layers of soils under tea may indicate higher uptake of K by the crop. The available P was different in tea cultivation and the forest soils in all different physiographic positions and was significantly higher in the surface horizons of the summit under the forest land use. Organic carbon was higher in forest soils with the exception of the soils developed on foot slope position in which the SOC was not significantly different. The SOC is a labile fraction and is highly sensitive to land use change and cultivation (Ashagrie *et al.,* 2005). The SOC was significantly higher, about 6% in the surface of the forest soils formed on the summit position. The SOC in the cultivated soils was always lower than the adjacent forest soils. In addition, bulk density values increased significantly in the tea soil due to lower amount of SOC. These results were in accord with those of (Khormali *et al.,* 2009), who also reported higher BD in deforested and continuously cultivated lands. Soil pH and CEC increased significantly in forest soils (Table 3). The movement and translocation of clay particles from the surface horizons of tea soils and accumulation at the foot slopes have contributed to higher amount of clay, SOC, CEC and Fe_d content.

Figure 2 shows physiographic positions and classifications of the soils developed under natural forest and tea cultivation.

Table 1. Physical and chemical characteristics of soils at studied sites in forest.

Horizon	Depth cm	pH $CaCl_2$	CEC Meq 100 g^{-1}	K Mg kg^{-1}	P Mg kg^{-1}	N %	BS %	OC %	Fe_d %	Clay %	bρ gr cm^{-3}
Summit position				Typic Udorthent							
Oi	0-4	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
A	4-20	4.04	35.4	200.4	10.7	0.468	33	6.6	0.45	19.2	1.14
AC	20-32	4.15	23.4	86.2	10	0.164	27	2.92	0.52	29.2	1.16
Cr_1	32-50	4.13	18.6	78.8	8.1	0.026	31	1.29	0.50	27.1	1.18
Cr_2	50-90	4.21	16.5	44.1	4.8	0.014	35	1.29	0.48	25.1	1.21
Cr_3	90-115	4.34	10.4	39.2	4.3	0.006	51	1.21	0.32	15.1	1.26
Cr_4	115-150	4.32	7.54	31.6	4	0.006	53	0.08	0.30	14.1	1.30
Shoulder position				Typic Udorthent							
Oi	0-2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
A	2-15	4.03	19.2	274.17	10.5	0.244	33	4.48	0.47	19.2	1.23
Cr_1	15-55	4.3	10.3	58.89	4.7	0.004	49	1.21	0.31	15.1	1.27
Cr_2	55-95	4.27	9.7	54.249	4	0.004	61	1.21	0.28	13.1	1.31
Footslope position				Ultic Hapludalfs							
A	0-25	4.44	18.6	147.42	8.7	0.254	39	3.25	0.51	21.1	1.32
Bt_1	25-57	4.47	16.5	76.44	4.9	0.058	36	1.75	0.58	25.1	1.31
Bt_2	57-84	4.45	26.79	132.48	6.8	0.038	33	1.44	0.64	49.2	1.34
Bt_3	84-110	4.77	23.95	92.82	6.3	0.026	40	0.27	0.63	47.1	1.36
C	110-150	4.89	17.73	80.34	4.5	0.002	40	0.04	0.41	27.3	1.40

Table 2. Physical and chemical characteristics of soils at studied sites in tea cultivation.

Horizon	Depth cm	pH $CaCl_2$	CEC Meq 100 g^{-1}	K Mg kg^{-1}	P Mg kg^{-1}	N %	BS %	OC %	Fe_d %	Clay %	bρ gr cm^{-3}
Summit position				Oxyaqic Dystrudept							
Ap	0-25	3.6	27.5	44.88	6.4	0.24	13	3.78	0.84	19.5	1.16
C_1	25-60	3.96	13.4	47.78	3.4	0.034	28	.12	0.41	24.1	1.29
C_2	60-90	3.95	10.8	44.39	3.2	0.052	34	0.12	0.4	20.1	1.30
$2Cg_1$	90-120	3.9	22.8	120.9	3.7	0.004	54	0.35	0.59	36.2	1.32
$2Cg_2$	120-150	4.07	19.7	91.69	3.6	0.004	66	0.31	0.45	38.2	1.31
Shoulder position				Ultic Hapludalfs							
Ap	0-18	3.58	12.5	186.81	5.4	0.198	18	2.69	0.42	14.1	1.32
Bt	18-56	3.76	24.43	77.61	4.7	0.024	38	1.52	0.63	47.2	1.41
Cr_1	56-90	4.06	17.25	54.25	4.1	0.012	45	1.36	0.45	26.2	1.53
Cr_2	90-128	4.08	16.72	46.60	3.9	0.002	50	0.74	0.4	24.1	1.67
Cr_3	128-150	4.05	16.36	38.80	3.9	0.002	62	0.72	0.38	20.1	1.81
Footslope position				Ultic Hapludalfs							
Ap	0-29	3.66	15.2	101.1	6.7	0.216	17	3.08	0.46	16.1	1.37
ABt	29-57	3.8	12.82	23.32	4.4	0.03	22	1.4	0.48	22.1	1.32
Bt_1	57-90	4.19	30.43	117.0	5.2	0.03	61	0.27	0.52	54.2	1.38
Bt_2	90-120	4.24	34.3	131.70	3.7	0.052	39	0.12	0.65	62.3	1.41
Btg	120-138	4.22	31.9	137.08	3.6	0.024	41	0.35	0.62	60.5	1.45
BCtg	138-160	4.21	31.7	130.26	3.2	0.072	42	0.43	0.59	54.1	1.52

Illuvation of clays was more prominent in the soils formed under the tea plantation due to higher rate of weathering and leaching processes. This resulted in higher development of soils formed under the tea cultivation in all positions. More prominent and developed argillic horizons were observed in the foot slopes due to a stronger pedogenic process. Table 3 shows that that

Table 3. Comparison of the means of soil properties on different slope positions in two different land uses.

Physiographic position	Land use	pH $CaCl_2$	CEC Meq 100 g^{-1}	K Mg kg^{-1}	P Mg kg^{-1}	N %	BS %	OC %	Fed %	Clay %	ρb gr cm^{-3}
Summit	Tea	4.1^{c}	27.34^{b}	37.05^{e}	6.2^{b}	0.243^{bc}	14^{d}	3.57^{c}	0.78^{a}	19.7^{b}	1.16^{d}
	Forest	5.2^{b}	32.23^{a}	191.5^{b}	11.53^{a}	0.451^{a}	35^{b}	6.56^{a}	0.47^{c}	19.2^{b}	1.13^{d}
Shoulder	Tea	4.2^{c}	13.36^{d}	150.15^{c}	5.56^{b}	0.185^{c}	17^{c}	2.42^{e}	0.44^{d}	15.16^{d}	1.31^{b}
	Forest	5.1^{b}	20.56^{b}	281.19^{a}	7.83^{ab}	0.227^{bc}	35^{b}	4.29^{b}	0.47^{c}	19.8^{b}	1.22^{c}
Foot slope	Tea	4.3^{c}	15.4^{d}	116.22^{d}	6.7^{b}	0.21^{bc}	16^{c}	3.11^{d}	0.46^{c}	17.53^{c}	1.38^{a}
	Forest	5.4^{a}	17.93^{c}	134.5^{cd}	8.86^{ab}	0.252^{b}	38^{a}	3.27^{cd}	0.51^{b}	21.13^{a}	1.31^{b}

clay content was higher in the surface horizons in forest soils than in the tea soils.

Clay Mineralogy

X-ray diffractograms of the soil clay fraction (< 2 μm) are presented in Figures 3-4. The Mg-saturated samples after glycerol solvation showed d-spacing expansion beyond 14 Å, which indicates the presence of smectites. K-saturated clay samples at 25°C showed that the 14 Å XRD peak shifted to lower d-spacing clay minerals and the intensity of the 10 Å peak increased. This indicates the presence of vermiculite in the clay fraction. The 12 Å diffraction peak of Mg-saturated and glycerol-solvated samples suggested that illite might be interstratified in part with vermiculite, as shown by the broad peak intensity in the 10 to 14 Å spacing. The XRD patterns for the Mg - clays showed low intensity 10 Å peaks in all clay samples, indicating the presence of small amounts of illite in the soil studied. Kaolinite was also identified from its 7.2 and 3.6 Å reflections. Both XRD peaks were weakened when K-saturated clays were heated to 550°C. A tiny XRD peak at 4.26 Å indicated the presence of small amounts of quartz. The XRD pattern of the clay fraction from the Bt_2 horizons of the soils studied in both forest and tea cultivation (Figures 3-4) showed that the 14 Å peak collapsed and shifted toward 10 Å when the K-saturated clay sample was heated at 550°C. The 14 Å peak also collapsed to 10 Å spacing after heating at 300°C. These indicate the persence of smectite due to expansion of d - spacing beyond 14 Å in Mg-saturated samples with glycerol solvation. This confirms the presence of hydroxy-interlayered vermiculite (HIV) in the clay fractions. X-Ray analysis indicated that vermiculite and vermiculite-illite mixed layers as well as hydroxy interlayered clay minerals (HIV) were the major clay minerals in all horizons. The amount and type of clay minerals were almost similar throughout the soil profiles in tea and forest soils.

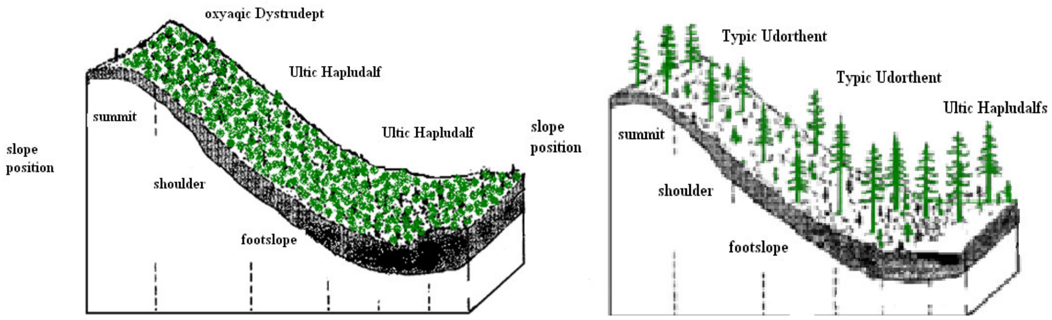

Figure 2. Physiographic positions and classifications of the soils developed under natural forest and tea cultivation.

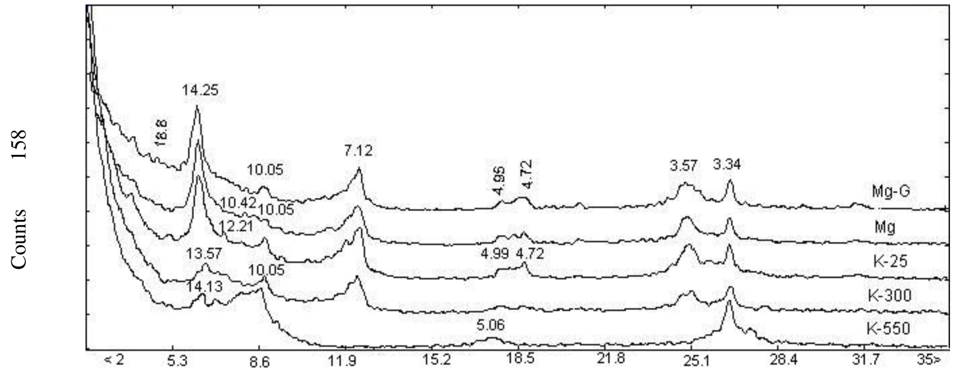

Figure 3. X-ray diffractograms of the clay fraction separated from the Bt_2 horizon of soil at footslope site in forest.

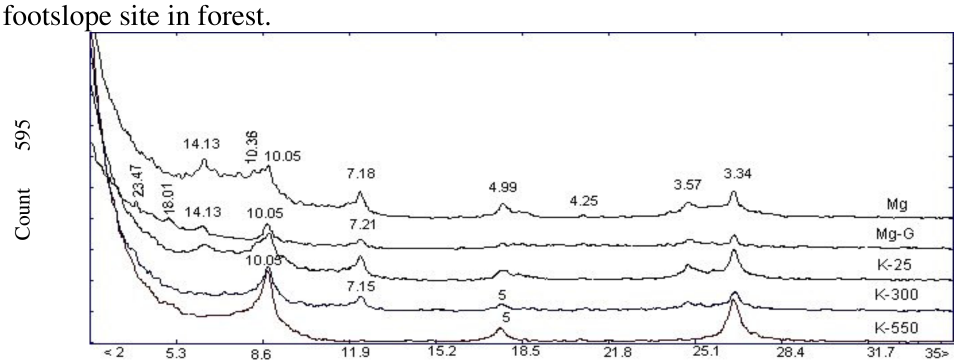

Figure 4. X-ray diffractograms of the clay fraction separated from the Bt_2 horizon of soil at footslope site in tea.

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CONCLUSIONS

This study indicated that land use change from deciduous forest to tea cultivation over a long time span, over 50 years, influenced physico-chemical properties of soils particularly organic carbon, soil acidity and base saturation. It also impacted soil morphological development and translocation of clay fraction down to a thick argillic horizon. The amount of available K and P decreased significantly due to the land use change. The tea cultivation protected the soils from erosion and also maintained soil productivity due to no till practice and minimum soil disturbances under the prevailing farming system. The soil topography was also influential on most of the soil properties under forest and tea cultivation. Highly developed soils with thick argillic horizons occur in foot slopes.

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تاثیر تغییر کاربری اراضی بر خصوصیات خاک و کانی شناسی رس خاک‌های جنگلی تکامل یافته در منطقه دریای خزر ایران

ن. رضایی، م. ح. روزیطلب، و ح. رمضانپور

چکیده

تمامی مزارع چای در ایران در منطقه دریای خزر تحت جنگل‌های طبیعی برگ‌ریز تکامل یافته، متمرکز شده اند. این پژوهش به منظور مطالعه اثر تغییر کاربری اراضی (از جنگل به چای) بر برخی خصوصیات فیزیکی، شیمیایی و کانی‌شناسی خاک در آب و هوای مرطوب و چشم‌انداز کوهستانی در شمال ایران انجام شد. سه ترانسکت در جهت شمال تا شمال غربی در هر دو اراضی چای و جنگل انتخاب شدند. مجموعا ۱۸ پروفیل در موقعیت‌های مختلف ژئومورفیک قله شیب، شانه شیب، پای شیب حفر گردیدند و ویژگی‌های مورفولوژیکی خاک شرح داده شدند .نمونه‌های خاک از هر افق مورد تجزیه قرار گرفت. در هر ترانسکت طرح آزمایشی در قالب طرح کاملاً تصادفی با دو فاکتور به روی تکرارهای سطحی انجام شد. نتایج نشان دادند که پس از تغییر جنگل به کشت چای، اسیدیته، ظرفیت تبادل کاتیونی، مقدار رس و کربن آلی خاک کاهش معنی داری در سطح احتمال ۱ درصد یافته بود اما وزن مخصوص ظاهری در مقایسه با خاک‌های جنگلی افزایش یافته بود. نتایج کانی شناسی رس نشان داد که ورمی کولیت، ورمی کولیت - ایلیت مختلط و هیدروکسی بین لایه‌ای اجزای اصلی رس بودند. خاک‌های زیر کشت چای تکامل یافته تر و دارای افق‌های آرجیلیک برجسته تر بوده و شامل میزان رس بیشتری در افق‌های پایین‌تر در تمام موقعیت‌های فیزیوگرافی می‌باشند.

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