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Long term effects of deforestation on soil attributes: case study, Northern Iran

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ABSTRACT
The objective of this study was to investigate the effects of land use change on soil properties in six different sites of Guilan Province, Northern Iran. The study sites were deforested approximately 40 years ago and changed to tea farms. Soil samples from 0 to 30 cm depth were collected in June 2016 and analyzed for total nitrogen (N), soil organic C (OC), available phosphorus, pH, electrical conductivity (EC), exchangeable Ca, Mg, Na, K, and Al, mean weight diameter (MWD) of aggregates, water stable aggregates (WSA) and bulk density. Soil properties of two soil land uses were compared. The results showed that after land use change from natural forest to tea farms, soil physical and chemical characteristics were changed. Land use change resulted in significant decreases in organic carbon, available potassium and pH. Reduction of annual organic matter input to soil as a result of deforestation and also rapid oxidation of organic matter in deforested places were responsible for a significant decrease in OC. Soil microbial respiration (SMR) also decreased significantly, following deforestation and decreasing the organic carbon. Changes in soil exchangeable Ca, Mg and available P in two land uses were not significant. The results indicated that tea farming for 40 years did not affect soil structural indicators (BD, MWD and WSA). Also decreasing the soil pH increased soil Al, so that the exchangeable Al in forest soils was 1.16 ppm, while in tea farm soils it was 1.9 ppm. Al toxicity is an important issue in this region.

Key words: Forest, Land use change, Soil properties, Al toxicity, organic carbon.

INTRODUCTION
Decreasing forest area in the north of Iran is one of the critical problems in recent years (Kelarestaghi *et al*. 2006). During the past 50 years, the cultivated lands of Iran have grown by more than nine times, increasing from 2.6 to 24.5 million ha. Land-use changes in Iran have been more rapid in the last 50 years than at any time in Iran's history and are expected to continue at this rate or speed up in the future. The coverage of regional forests in Iran has decreased with the development of arable land and population growth, economic development, technological advancement, and change in social and political situations (Haghdoost *et al.* 2013). Although improvement in the agricultural division increased productivity greatly during the last 50 years, intensive farming and mismanagement of the deforested areas brought environmental problems and soil effects such as soil erosion, acidification, soil compaction and pollution (Beheshti *et al*. 2012). The unfortunate increase in land degradation in Iran requires different management practices (Khotabaei *et al.* 2013). In many parts of Iran, the major factor in water resources decline is land use change that may cause ecological destruction and disruption (Mortezaii Frizhandi 2017).
The different land use changes, specifically conversion of natural forests to croplands, may result in significant alterations in soil processes and properties, and therefore soil functioning (Post & Kwon 2000; Celik 2005; Dawson & Smith 2007). Zhao *et al.* (2017) investigated the effects of land use on soil aggregates and suggested that land use affects the stability and size distribution of soil aggregates through the integration of soil organic matter and Fe and Al oxides. The land use changes in Iran, especially over the last century, have influenced soil quality, crop production and environmental sustainability (Hajabbasi *et al.* 1997; Raiesi 2007; Golchin & Asgari 2008; Emadi *et al*. 2009; Khormali *et al.* 2009).

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A common concern addressed by many of these studies is the resource degradation due to the decrease in the area under natural vegetation and its conversion to other types of land use and land cover that are human -managed systems.
In Orissa, India, conversion of forest into farmland led to a significant reduction in organic carbon, total N and C/ N ratios, but not in total and available P concentration (Sahani & Behera 2001). Similarly, Lal (1994) concluded that soils in western Nigeria deteriorated in chemical properties after deforestation and with cultivation time, regardless of differences in cropping systems. The changes that occurred elsewhere after deforestation and subsequent cropping are decreases in plant available nutrients (Lu *et al.* 2002) and microbial activity (Kiese *et al.* 2002). Celik (2005) investigated on Mediterranean soils in Turkey, and Khormali *et al.* (2009) on loess soils in semi-arid region of northern Iran, reported reducing of soil quality indices upon cultivation of native soils.
Soil organic matter content and dynamics are more informative and useful characters to study the influence of land use changes on soil functions (Beheshti *et al.* 2012). Post and Kwon (2000) emphasized the role of soil organic matter in improving soil physical, chemical and biological properties.
The land use is an important factor affecting SOC accumulation and storage in soils, which controls the magnitude of SOC stock and also greatly influences the composition and quality of organic matter in soils (John *et al.* 2005). Converting natural lands for crop production is the largest source of anthropogenic carbon emissions after fossil fuel burning, resulted in the release of about 200 Pg C over the past 250 years, globally (Fitzsimmons *et al.* 2004; Khormali *et al.* 2009).
The biological soil quality attributes are relatively responding rapidly to management compared to other variables, hence playing a considerable role in monitoring the effects of cultivation after deforestation and clear cutting on soil quality (Powlson *et al.* 1987). Microbial respiration and the metabolic quotient, have been increasingly recognized as sensitive indicators of soil quality and function in relation to land use and management (Bergstrom *et al.* 1998; Chen *et al.* 2000).
Aluminum (Al) is a very abundant element making up on average 7% of the weight of the earth crust as alumino - silicate minerals. However Al is not an essential element for plant growth or animal production. Soil pH or acidity is the most important factor that influences the form of Al in the soil determining whether this is potentially soluble and damages to sensitive plant roots or not. Some components of organic matter can form complexes with Al in the soil solution, thus make it unavailable to plants. Land use change by changing OC and pH can affect soil Al content and toxicity.
Knowledge of the influence of cultivation and different cropping systems following forest conversion on soil physical and chemical attributes, and SOC dynamics, is needed to determine the sustainability of adopted agricultural management practices (Nael *et al.* 2004; Golchin & Asgari 2008), establishing effects of land use and land cover changes on soil attributes have implications for devising land management strategies for sustainable use.
The information can be employed to forecast the likely effects of any potential changes in land use on soil attributes.
Thus, the objectives of this study was to evaluate the changes in soil attributes (physical, chemical and biological attributes) after conversion of native forest to tea farm.

MATERIALS AND METHODS

1. Description of the study area

The study area is located in Guilan Province, Northern Iran (from 37° 07′ 31″ to 37°14′ 45″ N longitude, and from 49°14′ 09″ to 50° 17′ 06″ E latitude). The study was carried out in summer 2016. The climate was humid subtropical with an average annual rainfall and temperature of 1200 mm and 15.8$^{\circ C}$, respectively.
The soil moisture and temperature regime are udic and thermic, respectively.
The study area were included six locations consisting of an undisturbed forest and a completely deforested area which has been clear cut and changed to tea farm for 40 years.
Totally, 36 soil samples (0-30 cm depth) were collected from six paired sampling locations under each of two adjacent land use/land cover types (native forest and tea farm).
In each of these locations, forest and tea farm were next to each other and had same physiography and parent material. The soil textures of the study areas were silty loam, loam and silty clay loam in surface of two land uses.

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2. Laboratory analyses

Three samples were collected at each location for each land use and immediately sealed in plastic bags to prevent moisture loss. The soil samples were transported back to the laboratory.

Soil respiration was measured using aerobically incubated in a 1 L sealed glass jar. Carbon dioxide (CO_2) evolved from soil was trapped in 0.1 N NaOH and measured by titration after 7 days (Alvarez *et al.* 1995).

Soil bulk density was determined by the core method (Blake & Hartge 1986). Soil samples from each location were air-dried and subsamples (< 2 mm) were analyzed for some physical, chemical and attributes of soil. Particle size distribution was determined using the hydrometer method (Gee & Bauder 1996), organic carbon using the wet – digestion method (Walkley & Black 1934), soil reaction (pH) and electrical conductivity (EC) in the saturated extract of soil (Richards 1954) By pH-meter (METROHM, model 632) and EC meter (JENWAY, Model 4310), respectively. Available P was measured according to the standard method described by (Bray & Kurtz 1945). Total nitrogen (N) was determined using the Kjeldahl distillation method (Bremner & Mulvaney 1982).

exchangeable K, Na, Ca, Mg, and Al determinations were carried out following the procedures described by Rayment & Higginson (1992).

The method of Kemper and Rosenau (1986) was used to determine mean weight diameter of water stable aggregates (MWD) and water stable aggregates (WSA).

3. Statistical analyses

The experimental design was randomized complete block as split plot.

The main factor was land use and the secondary factor was location with three replications.

Descriptive statistical analyses including mean, standard deviation, coefficient of variation (CV), one-way analysis of variance (ANOVA) and mean comparison using t test (LSD) were conducted using SAS software (SAS institute 2000). Values of soil attributes differing at $p \leq 0.05$, were considered significant.

RESULTS AND DISCUSSION

In our study, the primary soil attributes were similar for both land uses, so the differences were related to the land use change. Effects of land use change were significant on soil pH and Al ($p < 0.01$) as well as on organic carbon (OC), soil microbial respiration (SMR) potassium (K) and sodium ($p< 0.05$). Despite the effect of sampling location on available phosphorus, Ca, and Na ($p < 0.05$) and Al, SMR and Bulk density ($P < 0.01$) were significant (Tables 1 and 2), but the locations had no clear trend.

Thus, some soil functions (parent materials, organisms, relief) were different. So, means of soil attributes in sampling locations were not compared with each other.

Table 1. Analysis of variance of effects of land use and location on some soil chemical attributes.

					Mean Square						
Source of variation	**DF**	**pH**	**EC(ds/m)**	**OC (%)**	**K(ppm)**	**P(ppm)**	**N (%)**	**Al**	**Ca**	**Mg**	**Na**
Location	5	0.096	0.24	1.21	85479	356*	0.007	8.14**	14.48*	2.01	3.06*
Repetition× Location	12	0.20	0.201	1.37	24785	72.035	0.005	1.03	1.34	1.27	0.56
Land use	1	13.8**	0.290	12.96*	235144*	9.507	0.025	52.85**	0.0.2	2.42	6.91*
Location× Land use	5	0.15	0.23	0.88	93147	138.438	0.006	6.73	5.6	0.43	2.71
Error	12	0.14	0.22	1.56	41883	97.670	0.009	0.52	4.91	2.6	3.83

EC: electrical conductivity, OC: organic carbon, K: potassium, P: available phosphorus, N: total nitrogen, Al: aluminum, Ca: calcium, Mg: magnesium, Na: sodium. * and **symbols represent significant effects at $P < 0.05$ and 0.01, respectively.

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Table 2. Analysis of variance of effects of land use and location on soil microbial respiration and some soil physical attributes.

	Mean Square				
Source of variation	**SMR**	**Clay (%)**	**Bd (g cm^{-2})**	**MWD**	**WSA**
location	6.74**	58.317	0.152**	1.45	1.99
Repetition× location	0.77	17.222	0.012	1.33	1.09
Land use	5.21*	2.250	0.098	0.03	0.07
Location× Land use	0.63	74.317*	0.032	1.94	1.29
error	749	58.317	0.152	0.005	30.63

SMR: soil microbial respiration, Bd: bulk density, MWD: mean weight diameter of aggregates, WSA: water stable aggregates. * and **symbols represent Significant effects at $P < 0.05$ and 0.01, respectively.

Soil pH and Al

In general, soil pH in forest land use was significantly higher than the tea farm. Soil pH influences plant growth directly via the effect of the hydrogen ions, and indirectly via effects on nutrient availability, the latter is more important (Brady 1985). Microbial activity and clay dispersion are also influenced by soil pH (Haynes & Naidu 1998). The lower pH values of the soils in the tea-cultivated area are due to the intensive application of phosphorus fertilizers as well as the addition of litter and plant residuals to the soils in tea farms.

In addition, the oxidation of nitrogen and sulfur could result in an intensified decomposition of soil organic matter in tea farms and subsequent reduction in the soil pH. The lower soil pH in tea farms can also be attributed to the more intense erosion and leaching processes. Decreased soil pH under cropping system, after deforestation is a common and serious problem that has been associated with decreased agricultural productivity in this soil type (Bolan *et al.* 1991; Moody & Aitken 1997; Rasiah *et al.* 2004).

The Al concentration in tea farm was significantly more than the forest land use (Table 3). Despite the soil was inherently acidic, further acidification of this soil under tea farm may lead to serious environmental problems including solubilization and leaching of aluminum into run off and the natural ecosystems. In general, the exchangeable Al under forest is low by an order of magnitude than the deforested system. The Al extraction procedure i.e. oxalic acid/ammonium oxalate, releases Al into solution phase which is (i) present already in soil solution, (ii) adsorbed at exchange sites of mineral, and (iii) adsorbed by soil organic matter (Rayment & Higginson 1992). Significant negative correlations between Al and SOC suggest that large C-pools in soil reduce the amounts of Al in solution phase (Rasiah *et al.* 2004).

Thus, higher Al in the tea farm compared to forest lands is at least partially due to low contents of soil organic carbon, while higher Al under tea farm could also be attributed to lower pH, a phenomenon supported by strong negative correlation between Al and pH. Similar results have been reported by other authors (Adams *et al.* 2001; Chen *et al.* 2001; Rasiah *et al.* 2004). Al toxicity is an important issue in this region, such that, cropping reduces soil pH and organic matter, which in turn, increases Al in soil solution.

Electrical conductivity, Ca and Mg

The EC values of the forest land use and tea farm soils were 0.39 and 0.57 dS m^{-1}, respectively, but the difference among them was not significant ($p < 0.05$). Kizilkaya & Dengiz (2010) stated that changing the forest to cultivated land increased EC value.

EC content represents soil soluble salts and probably the adding chemical fertilizer is a reason for increasing EC in tea farms. The concentration of exchangeable Ca^{2+} and Mg^{2+} did not significantly differ in two land use types. This indicates that exchangeable Ca^{2+} and Mg^{2+} are not influenced by land use in this area.

Soil organic carbon and nitrogen

The total N had no significant difference between forest and tea farm land uses. Therefore, after 40 years of tea farming, at the soil surface (0 – 30 cm), total nitrogen has not affected by land use change similar to those reported

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in literature (e.g., Moges *et al.* 2013). N is the only nutrient that can be biologically "produced" on farm. Root decomposition and uptake by plants had an important role in concentration of N. However, the concentration of total nitrogen followed a similar pattern to organic carbon distribution and in the natural forest, it was relatively higher than in the tea farm. In contrast, Khresat *et al.* (2008) reported a significant difference in TN between the forest and cultivated land due to differences in soil organic matter content, intensities of erosion, and cultivation. The relatively higher TN in the natural forest land use could be associated with the relatively higher organic carbon which in turn resulted from plant and root biomass as well as residues being returned to the soil system. The main reason for lower contents of total nitrogen comes from biomass removal during crop harvest and insufficient replenishment through manure or fertilizers. The nitrogen contents of the tea farm soils are slightly lower compared to the forest soils, because the majority of soil nitrogen is bound in organic matter (Khresat *et al.* 2008). The latter is often considered to be the most important indicator of soil quality and sustainable land management. The results showed the significant difference between different land use types for soil organic carbon (SOC). So that, these values varied from 3.42 for natural forest to 2.22 for tea farm (Table 3). Hajabbasi *et al.* (1997) reported that deforestation and subsequent tillage practices resulted in nearly a 50% decrease in SOM for the soil depth of 0–30 cm over 20 years in the central Zagrous Mountains in Iran. Significant reduction of SOC by changing the forest or rangeland to agriculture lands has been reported in literature (Evrendilek *et al.* 2004; Chidumayo and Kwibisa 2003; Ayoubi *et al.* 2011, shahab *et al.* 2013). Cultivated soil generally have lower organic matter content compared to native ecosystems, since cultivation increases aeration of soil, which in turn, enhances decomposition of SOM. Similar result was found by Jiang *et al.* (2006), who indicated that soil organic matter content deceased from 38.02 g kg^{-1} to 25.76 g kg^{-1} in the past 20 years after transformation of forest into cultivated land. It seems that higher rates of microbial decomposition and nitrogen transformation took place at the tea farms, therefore, the SOM was decreased.

Available phosphorus and exchangeable sodium and potassium

The concentrations of exchangeable Na^+ and K^+ in tea farm were significantly ($P < 0.05$) lower than in the natural forest. However, the soils in the study area were not sodic. K varied from 341.31 mg kg^{-1} in the forest to 179.67 mg kg^{-1} in the tea farm. These results are similar to the findings of Lemenih *et al.* (2005). Intensive cultivation and application of urea which is acidifying fertilizer might be also an important reason for the lower K^+ in tea farm (*Hajabbasi et al.* 1997). Furthermore, available phosphorus (P) did not show the significant difference between two land use types, but natural forest had slightly lower P than the tea farm soils (Table 3). The lower P content in forest can be related to phosphorus fixation (Yimer *et al.* 2006). Similar finding i.e. insignificant change in available P following deforestation in tropical area of India was reported by a (Sahani & Behera 2001).

Table 3. Effects of land use types on soil attributes.

Soil attributes	forest	Tea farm
pH	5.51^a	4.26^b
Al (ppm)	1.16^b	1.9^a
EC(dS m^{-1})	0.39^a	0.57^a
Ca (meq l^{-1})	2.6a	2.65a
Mg (meq l^{-1})	1.28a	1.8a
OC (%)	3.42^a	2.22^b
TN (%)	0.28^a	0.23^a
P(ppm)	13.48^a	14.51^a
Na(meq l^{-1})	236^a	167^b
K (ppm)	341.31^a	179.67^b
SMR (g CO_2 kg $soil^{-1}$)	0.238^a	0.191^b
Bd (g cm^{-1})	1.46^a	1.47^a
MWD (mm)	1.069^a	1.065^a
WSA (%)	56.15^a	55.67^a

MWD: mean weight diameter of aggregates, WSA: water stable aggregates, OC: organic carbon, TN: total nitrogen, P: phosphorus, K: potassium, Mg: magnesium, Ca: calcium, Na: sodium, Al: aluminum, EC: electrical conductivity

Soil microbial respiration

The average of SMR under tea farm (0.19 g CO_2 kg^{-1} soil) was significantly lower than that under the forest land use (0.24 g CO_2 kg^{-1} soil). The reduction in SOM following deforestation influences the SMR as an important soil biological quality indicator. Enhanced microbial activities in soils under natural forest are related to greater

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contents of available organic C (Nael *et al.* 2004). Kiani *et al.* (2007) found that the addition of fresh plant residues and organic matter in the forest is important to increase SMR. Inappropriate and agricultural management practices increases the loss of organic matter, leading to the subsequent decrease in microbial population and lower respiration (Khormali *et al.* 2009). It seems that addition of litter and organic matter in forest land use has increased SMR in our study.

Bulk density, MWD and WSA

Aggregate stability is considered to be a characteristic that provides information on soil quality which is highly influenced by land use and management (Chrenková *et al.* 2014). Soil bulk density is also an indicator of soil compaction which is related to soil strength and in turn, is inversely related to susceptibility to compaction (Pimm 1984). Although some previous studies have shown an increase in soil bulk density, MWD and WSA due to deforestation (Kiani *et al.* 2007; Khormali *et al.* 2009, Steffen *et al.* 2017, Zhao *et al.* 2017), the values of these structural attributes of soils between two land uses were not significantly different ($p > 0.05$). It may be due to the effects of tea roots. Although organic matter in cultivated soils has less physical protection than that in the uncultivated soils (because tillage periodically breaks up macro aggregates and exposes previously protected organic matter in soil macro aggregates), but tea is perennial plant and the tillage practices in tea farms were not carried out annually. Therefore, soil structure was not influenced by land use change.

CONCLUSION

As a result of high growth rate of population and consequent needs for food and fiber requires, each year hundreds hectares of the forest in northern of Iran are deforested and converted to the croplands.

Variation in soil attributes with respect to land use change for 40 years were investigated in the Guilan Province, Northern Iran. To examine the effect of deforestation, some soil physical and chemical attributes were measured and compared between forest and tea farms. Clearing and cultivation of forested lands resulted in deterioration of soil attributes compared to soils under natural forest.

The results of this study showed that there were significant differences ($p < 0.05$) between two land uses. Based on the results, soil nutrient in the natural forest was higher than tea farms. Organic matter and microbial respiration decreased due to deforestation and subsequent intensive human practices. The results indicated higher contents of potassium and organic carbon in the soil surface (0-30 cm depth) in natural forest than in the tea farms. Management practices that increase OC in the system should be included, when the land is continuously cultivated.

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اثرات طولانی مدت جنگل تراشی بر ویژگی‌های خاک: مطالعه موردی، شمال ایران

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چکیده

هدف از این پژوهش، بررسی اثرات تغییر کاربری زمین بر ویژگی‌های خاک در شش منطقه مختلف استان گیلان در شمال ایران بود. مناطق مورد مطالعه تقریبا ۴۰ سال قبل جنگل تراشی شدند و به کشت چای تغییر یافتند. نمونه‌های خاک از عمق صفر تا ۳۰ سانتی‌متری در تیرماه ۱۳۹۵ جمع‌آوری شدند و نیتروژن کل (N)، کربن آلی خاک (OC)، فسفر قابل دسترس، pH، هدایت الکتریکی (EC)، کلسیم، منیزیم، سدیم، پتاسیم و آلومینیم تبادلی، میانگین وزنی قطر خاکدانه‌ها (MWD) خاکدانه‌های پایدار در آب (WSA) و جرم مخصوص ظاهری آنها اندازه‌گیری شد. ویژگی‌های خاک در دو کاربری مقایسه شد. نتایج نشان داد بعد از تغییر کاربری از جنگل طبیعی به مزارع چای، ویژگی‌های فیزیکی و شیمیایی خاک تغییر پیدا کردند. تغییر کاربری اراضی باعث کاهش معنی‌دار کربن آلی خاک، پتاسیم قابل دسترس و pH شد. کاهش سالانه ورود ماده آلی به خاک در نتیجه جنگل تراشی و همچنین اکسداسیون سریع ماده آلی در مناطق جنگل تراشی شده عامل کاهش معنی‌دار کربن آلی بود. تنفس میکروبی خاک (SMR) نیز به دلیل جنگل تراشی و کاهش کربن آلی خاک، به طور معنی‌داری کاهش یافت. تغییر در کلسیم و منیزیم تبادلی و فسفر فراهم در دو کاربری معنی‌دار نبود. نتایج نشان داد کشت چای پس از ۴۰ سال تاثیری بر شاخص‌های ساختمان خاک (BD، MWD و WSA) نداشت. همچنین کاهش pH خاک، Al خاک را افزایش داد؛ به طوری که Al تبادلی در خاک‌های جنگل ppm ۱/۱۶ بود؛ در حالی که در خاک‌های مزارع چای ppm ۱/۹ بود. سمیت Al موضوع مهمی در این مناطق است.

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