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Impacts of changes in land use/cover on soil microbial and enzyme activities

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ABSTRACT

Microbial and enzyme activities are increasingly being recognized as sensitive indicators of soil quality. This study aims to determine the impacts of different kinds of land use/cover, i.e. virgin natural forest (VNF), degraded natural forest (DNF), alder plantation (AP), sequoia plantation (SP), improved fallow (IF) and home garden (HG) areas on soil properties in northern Iran. Five composed samples per land use/cover were taken from the top 10 cm of the soil.

Soil microbial respiration was found to be in the ranked order of AP > VNF > HG > DNF > IF ≈ SP areas, being more than one-and-a-half-fold under AP compared with SP. The values of microbial biomass carbon were almost two times higher under SP ≈ VNF than under IF ≈ HG areas. Microbial biomass nitrogen was found to be significantly higher under AP ≈ VNF than in the other kinds of land covers. AP ≈ VNF significantly increased the activities of urease and acid phosphatase, whereas greater activities of invertase occurred in AP ≈ VNF ≈ SP sites. Arylsulphatase activity was significantly higher to be significantly higher under AP in comparison with VNF > HG > DNF > SP > IF areas. As a conclusion, alder (*Alnus subcordata* C. A. Mey.) plantation improved the soil quality to levels similar to natural forest ecosystems. This research recommends the preservation of natural forests to increase soil quality and a plantation with suitable native broad-leaved species and forestation plan management to rehabilitate degraded natural forests.

1. Introduction

The growth rate of population caused by urbanization is affected by changes in population, wealth, social trends (for example, household size and lifestyle choices), and transportation costs (Reginster and Rounsevell, 2006). The rapid growth of populations in northern Iran requires additional farmlands for the production of crops. One way is to expand the tillable area by clear cutting the forests and converting pastures into agricultural land. Nowadays, deforestation and land use changes have caused serious problems in northern Iran (Kooch et al., 2016a). Comparisons of land use projects between 1988 and 2004 in the northern forests of Iran showed that 12,152 ha of forests were destroyed during this period—an alarming rate—in the majority of the areas of Mazandaran province (Mirakhorlou et al., 2006).The conversion of forests and grasslands into agricultural lands is one of the main concerns worldwide in the context of environmental degradation and global climate change (Kooch et al., 2016a). Apart from agricultural land use, forest plantations have become common landscapes across many parts of the world (Kooch et al., 2016b) as, in addition to timber and agricultural products (such as fruits and latex), they can improve other ecosystem services, such as water regulation, soil fertility, and carbon (C) and nitrogen (N) stocks in soil (Humpenoder et al., 2014). Recent inventories in northern Iran have shown that around 200,000 ha of degraded land have been reforested, 40,000 ha of which consist of needle-leaved species (Kooch and Zoghi, 2014).The widespread changes in land use/cover may result in significant variability of soil processes and properties, and, therefore, soil functioning (Celik, 2005; Dawson and Smith, 2007). Numerous reports have highlighted that changes in land use/cover would influence soil fertility and quality indicators because of subsequent alterations in abiotic and biotic factors and also soil organic matter (SOM) stabilization (Solomon et al., 2000; Grünzweig et al., 2003; Raiesi, 2007). Land use/cover changes would primarily lead to remarkable alterations in C and N inputs and dynamics (Kooch, et al. 2016), which subsequently govern soil physical, chemical and microbial processes (Celik, 2005; Raiesi, 2007; Li et al., 2009). Measurements of the characters related to SOM, such as microbial respiration (MR), substrate induced respiration (SIR), microbial biomass C (MBC)-N (MBN), nitrate (NO_3)-ammonium (NH_4) concentration and N mineralization, could better reflect changes in soil quality and productivity, which alter nutrient dynamics. This reflection is based on the rapidly changing capacity of both C and N forms (Kara and Bolat, 2008). These characters can also provide an assessment of

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SOM changes induced by management practices, such as natural forest, coniferous and deciduous plantation, home garden and agriculture areas (Beheshti et al., 2012).

Soil enzyme activities are important indicators of microbiological and biochemical processes because they are often involved in SOM decomposition and synthesis, nutrient cycling and availability, and soil fertility and quality (Nannipieri et al., 2002; Bastida et al., 2008). Soil enzyme activities were assayed for their potential to reflect the effects of land use/cover changes on soil quality (Lagomarsino et al., 2011; Wang et al., 2012), and there has been growing evidence that enzyme activities are potential early and sensitive indicators of changes in soil conditions and properties following changes in soil use/cover (Gamboa and Galicia, 2011). The assay of soil enzyme activities can be used as a suitable indicator for quantifying and monitoring changes in microbial community structure and activity as well as SOM dynamics in response to anthropogenic disturbances (Trasar-Cepeda et al., 2008).Very little is known about the effects of changes in land use/cover on soil microbial and enzyme activities in central Asia, especially by including natural forest, plantation and cultivated ecosystems. The forests of Iran are among the oldest in Asia and the northern hemisphere. The vast area of the country, its diverse climate, and the rich diversity of plant species in different geographical regions, make this part of the Middle East attractive to botanists, biologists and foresters. The Hyrcanian vegetation zone, also called the Caspian forest, is a green belt stretching over the northern slopes of the Alborz mountain ranges and covers the southern coasts of the Caspian Sea. These forests are one of the last remnants of natural deciduous forests in the world (Talebi et al., 2014).The future of northern Iran is connected with the wise and efficient management of its natural resources and restoration of its environment. In this study, we focused on the six main and common kinds of land use/cover, including (1) virgin natural forest (VNF), (2) degraded natural forest (DNF)covered by hornbeam and Ironwood tree species, (3) alder plantation (AP), (4) sequoia plantation (SP), (5) improved fallow (IF) and (6) Agroforestry type of home garden (HG) areas. Also, an attempt has been made to establish the relationships among kinds of land use/cover, soil microbial (MR, MBC and MBN), enzyme activities (urease, acid phosphatase, aryl sulphatase and invertase), and physico-chemical (bulk density, water content, pH, organic carbon, total nitrogen and available nutrients) properties. We tested the following hypotheses: (1) forest degradation decreases both microbial and enzyme activities in the topsoil, and (2) alder plantation improve soil quality compared to needle-leaved plantation and non-forest covers.

2. Materials and methods

2.1. Study area

The study area is located at Tilekenar district of Salmanshahr in Mazandaran province, in the north of Iran, between 36°39′36″ N–36°40′01″ N and 51°09′55″ E–51°10′18″ E on the coast of the Caspian Sea. Study stands were located at an altitude of 250 m above sea level and with gentle slope (0–5%). The mean annual rainfall is 1300 mm and means annual temperature is 17 °C at the Noushahr city metrological station, which is 5 km from the study area. Based on the meteorological station, there is a dry season between May and August (Fig. 1).According to the USDA Soil Taxonomy, soils can be classified as silty-clay-loam Alfisols, developed on dolomite limestones belonging to the upper Jurassic and lower Cretaceous periods.This area was previously dominated by degraded natural forests containing native tree species such as *Quercus castaneifolia*, *Zelkova carpenifolia*, *Parrotia persica*, *Carpinus betulus*, *Diospyros lotus* and *Buxus hyrcana*. While 27 years ago, after clear cutting (in some areas of degraded natural forests), reforestation has been done (within 3 × 3 m spaces) in this area, with some native species, including alder (*Alnus subcordata* C. A. Mey.) with 2.10 ha, maple (*Acer insigne* Boiss.) with 1.72 ha, as well as exotic species of sequoia or redwood (*Sequoia sempervirens* (D. Don) Endl.)

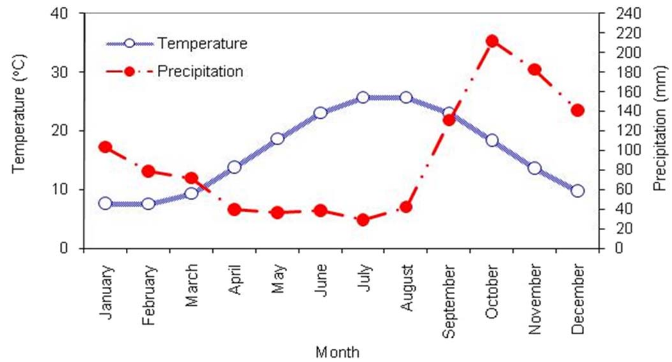

Fig. 1. Mean monthly temperature and precipitation in study area based on Noushahr city metrological station.

with 5.89 ha and mixed stand (maple and sequoia) with 4.87 ha. The stands were never fertilized. However, some areas were not afforested in 1989 and are now covered by degraded natural stand of *Carpinus betulus-Parrotia persica* (5.63 ha), and improved fallow (4.69 ha) and home garden (3.49 ha) areas (Gheibi, 2014).A detailed description of each site is reported in Table 1.

2.2. Soil sampling and laboratory analysis

In selecting land use/cover systems, care was taken to ensure the consistency in soil texture and topographical features (e.g., elevation, slope position, and aspect). One-and-a-half hectare areas (150 × 100 m) were selected for each land use/cover. Three soil profiles (25 cm × 25 cm) were dug along (at the beginning, the middle and the end) the five parallel transects in the central part of land use/cover, resulting in 15 soil samples for each site at a depth of 0–10 cm. Three soil samples of each transect were mixed and from each land use/cover five mixed soil samples, totally thirty (the experimental design was completely randomized block design, involving 6 land uses/covers × 5 replicates), were transferred to the laboratory (Raiesi and Beheshti, 2014). Soils were air-dried and passed through 2-mm sieve (aggregates were broken to pass through a 2 mm sieve).Part of the soil samples were immediately transferred to a cooled, insulated container for transport to the laboratory and were stored at 4 °C until they were processed. Bulk density was measured by Plaster (1985) method (clod method). Soil texture was determined by the Bouyoucos hydrometer method (Bouyoucos, 1962). Soil water content was measured by drying soil samples at 105 °C for 24 h. Soil pH was determined using an Orion Ionalyzer Model 901 pH meter in a 1:2.5, soil: water solution. Soil organic C was determined using the Walkey-Black technique (Allison, 1975). The total N was measured using a semi Micro-Kjeldhal technique (Bremner et al., 1982). Available P was determined with a spectrophotometer and the Olsen method (Homer and Pratt, 1961), and available K, Ca, and Mg (by ammonium acetate extraction at pH 9) were determined with an atomic absorption spectrophotometer (Bower et al., 1952).Soil MR was determined by measuring the CO_2 evolved in 3 days incubation experiment at 25 °C (Alef, 1995) and N mineralization was measured using a laboratory incubation procedure under controlled conditions (Bremer, 1965; Robertson et al., 1999). MBC and MBN were measured by fumigation-extraction method (Brookes et al., 1985; Sparling et al., 1990).The assay of the enzyme activities was based on the colorimetric determination of the product released by the enzyme following the methods described by Alef and Nannipieri (1995). Urease activity (EC 3.5.1.5) was determined using 200 mM urea as substrate under standard conditions (2 h at 37 °C). Acid phosphatase activity (EC 3.1.3.2) was measured using 15 mM *p*-Nitrophenyl phosphate disodium (PNP) as substrate in a modified universal buffer (MUB) at pH 6.5, incubated for 1 h at 37 °C. Arylsulphatase activity (EC 3.1.6.1) was assayed following incubation of the soils with *p*-