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C and N cycle monitoring under *Quercus castaneifolia* plantation

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ABSTRACT

In temperate forests, oak (*Quercus castaneifolia*) is an important species that grows along an elevation gradient from the flood prone plains to high topographical positions of the landscape. This study was aimed to monitor the effect of oak plantation on the soil C and N cycles and dynamics in the north of Iran. We tested the following hypotheses: (i) reclamation of deforested areas, planting of oak can improve topsoil fertility via forest floor inputs in the long-term, (ii) soil C and N microbial indices can be enhanced under oak plantation, 25 years after planting. For this purpose, three afforested oak stands with 15, 20, and 25 years old, besides a site without plantation, were selected and thirty samples per each site were taken from forest floor and soil ($20 \times 20 \times 10$ cm) layers and their physicochemical, biological, and enzymatic properties were assessed. The acquired data demonstrated that forest floor quality, physicochemical and biological properties and enzymatic activities (i.e. urease, acid phosphatase, arylsulfatase and invertase) have been changed over time of oak plantation. Moreover, the microbial activity of soil C and N include basal respiration (BR), substrate inducted respiration (SIR), microbial biomass carbon (MBC), Metabolic quotient (qCO_2), microbial entropy (MBC/C), carbon availability index (CAI), carbon management index (CMI), particle organic carbon (POC) and dissolved organic carbon (DOC) were significantly higher in the plantation areas than without plantation site. Oak plantation significantly improved the N microbial characteristics [NH_4^+, NO_3^-, N mineralization, microbial biomass nitrogen (MBN), particle organic nitrogen (PON) and dissolved organic nitrogen (DON)]. Under different land covers, soil microbial activities were more affected by variations in forest floor and soil chemical properties with higher ratio of C, N and available nutrients. Taken together, plantation with suitable native broadleaved species could be considered to rehabilitate degraded natural forests through improving soil quality. Findings also highlighted the importance of understanding C and N cycles in the plantation areas which could involve in global warming phenomena.

1. Introduction

The declining trend in the natural forest areas has long raised a global concern, mainly due to worry about economical poverty reduction as well as loss of forest environmental services including water filtration, soil erosion control, and microclimate modification (Trumbore et al., 2015). Iran is categorized as a Low Forest Cover Country (LFCC) covered with only 7.6% forest ecosystems (IUFRO, 2004). Hyrcanian forests are one of the most antique and momentous ecoregions in Iran and the last remains of natural deciduous forests in the world. These forests are located at the northern slopes of the Alborz mountains, with expanding about 1.9 million ha in the southern Caspian Sea (IUFRO, 2004), but unfortunately, the majority of these forests has been deforested because of human manipulation, urbanization, land-use changes and agricultural purposes (Kooch et al., 2015). Given the high destruction rate of the world's natural forests and population growth as well as the growing need for wood and other forest services, the importance and necessity of forestation is highly obvious to regenerate the degraded areas and to provide supplies of community (Yousefi et al., 2010; Rahimabady et al., 2015). Restoration of degraded forest areas could be accompanied by alterations in the physicochemical and biological properties of the soil, thus improving forest ecosystem services (Kooch et al., 2017a,b). Reforestation success and soil development are mainly associated to the selection of suitable tree species (Woś and Pietrzykowski, 2015); for example, establishing broadleaf species seems to be more effective and to grow well on degraded sites in the tropics than conifer ones (Parrotta et al., 1997). In temperate forests, oak (*Quercus castaneifolia*) is an important species with high economic value in Iran. It possesses the capability to grow along an elevation gradient from flood-prone area to high topographical positions up to 1000 m above sea level (a.s.l.) (Sabeti, 2009); that is, the tree can be found from the plateau, together with other

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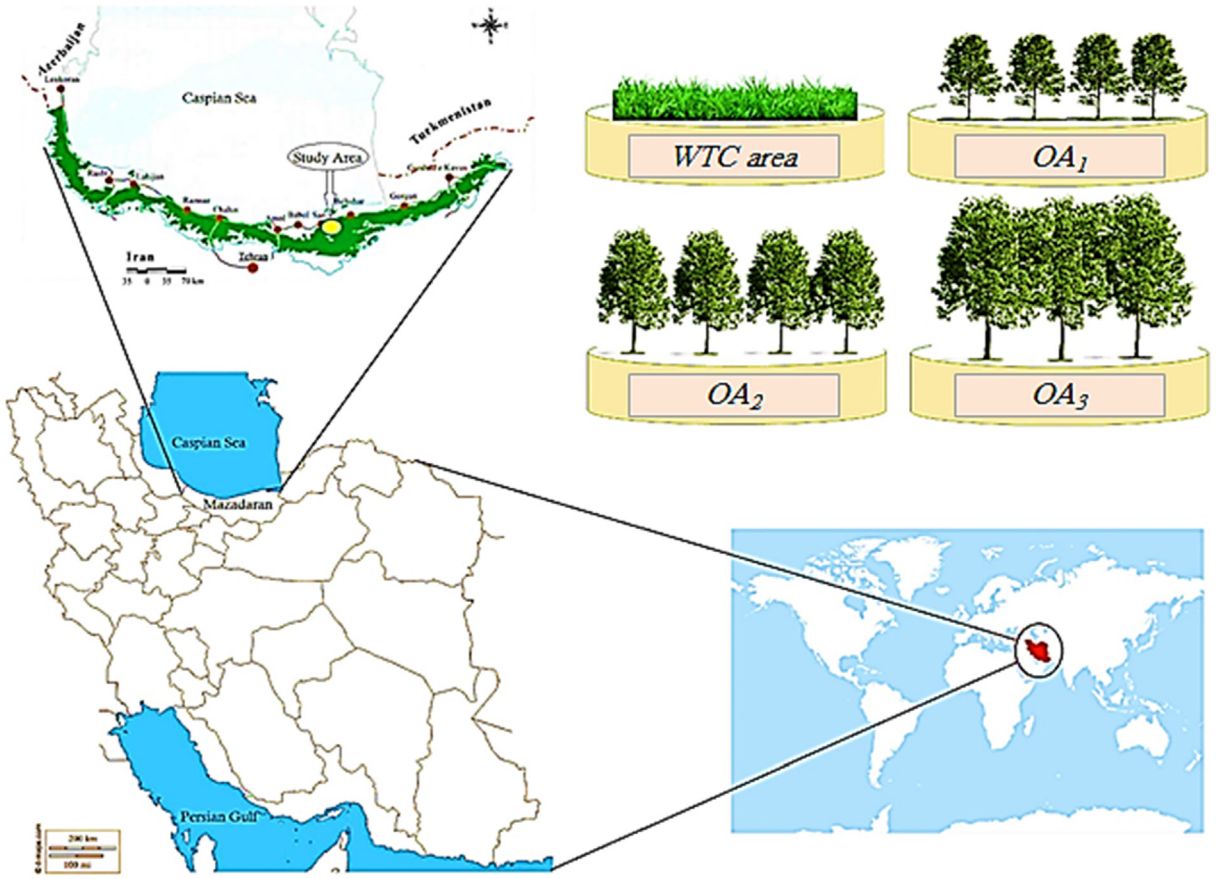

Fig. 1. Location of the study area in the northern Iran and treatments including WTC: Without Tree Cover area, OA1: 15 years old, OA2: 20 years old and OA3: 25 years old.

broad-leaved trees in particular with box tree, to where it is mixed with common hornbeam. The upper distribution limit of this species depends on both climate and soil properties and geomorphology, and at higher altitudes it prefers warm and sunny slopes (Talebi et al., 2005).

The optimal rotation age (ORA) might facilitate the greatest level of soil quality. Lack of information is available concerning ORA for oak plantation, and also no research has been conducted to evaluate its long-term effects on forest floor and topsoil in oak plantation in degraded natural forest lands. Over time, soil properties will be changed following forest aging, and in turn alters the soil C and N processes (Zhang et al., 2017). Forest plantation on the same sites with different ages mainly varies in productivity, canopy structure, and the quality and quantity of forest floor (Józefowska et al., 2017). Canopy properties directly and indirectly determine soil properties, microbial activities, and consequently the nutrient availability in forest stands (Prescott, 2002). Previous studies focused on changes in soil C and N cycles following afforestation in temperate forest lands (Bárcena et al., 2014; Nave et al., 2013). In temperate ecosystems, tree species have high importance in forest floor quality, soil organic matter (SOM) dynamics (Schmidt et al., 2011; Fekete et al., 2017), organic N content and N availability, biological and biochemical activities (Brzostek et al., 2013) that effect on microbial activities, C and N cycling (Fekete et al., 2012; Veres et al., 2015). Better understanding of changes in C and N microbial indicators dynamics in soils is especially important in plantation design, as they may reflect SOM quality and soil nutrients availability (Pereira et al., 2018). Kang et al. (2018) pointed that soil microbial indices are differ among plantations, in different ages, and agricultural lands. Based on their data, soil C and N concentrations and also enzyme activities significantly increased in older plantations. Not only the quantity and quality of SOM but also C and N inputs are the overriding controls on soil microbial biomass and activity (Kallenbach and Grandy, 2011). Hence, distinct organic amendments can stimulate microbial biomass through enhancing the labile organic matter on time frames from months to decades (Kallenbach and Grandy, 2011).

Soil biological and biochemical properties have been suggested as indicators of soil quality due to their sensitivity to both natural and anthropogenic factors (Sun et al., 2015; Utobo and Tewari, 2015). Microbial responses to various soil management systems and subsequent effects on nutrient cycling are currently being considered (Vacheron et al., 2013). Enzymatic activities involved in nutrient cycles are suitable indicators as they provide information about the soil microbiological status and soil physicochemical properties (López-Aizpún et al., 2018). However, studies reporting the changes in microbial properties of C and N are still lacking in the temperate tree plantation soils (Mori et al., 2016). Owing to high sensitivity of the soil microbial community to land management, microbial activities seem to be reliable indicators for soil quality (Utobo and Tewari, 2015), and it is necessary to identify and describe bio-geochemical cycles at a regional spatiotemporal scale. Thus, the study was aimed to evaluate physicochemical, biological and biochemical properties of soil and forest floor quality in three oak plantations with different ages, to assess the influence of stand age on soil C and N microbial indices, to test the hypotheses that (i) reclamation of deforested areas and planting of oak, can improve topsoil fertility via forest floor inputs in the long-term, (ii) soil C and N microbial indices can be enhanced under oak plantation, 25 years after planting. It is expected that the results of this study will provide some scientific bases for further understanding of the long-term afforestation effect and help to optimize degraded forest lands and reducing climate changes.