Ecological Indicators 50 (2015) 173–185

Contents lists available at ScienceDirect

Ecological Indicators

journal homepage: www.elsevier.com/locate/ecolind

Microbiological indicators of soil quality and degradation following conversion of native forests to continuous croplands

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ARTICLE INFO

Article history:
Received 20 May 2014
Received in revised form 31 October 2014
Accepted 10 November 2014

Keywords:
Cultivation
Deforestation
Microbial activity
Microbial biomass
Enzyme specific activity
C loss

ABSTRACT

Deforestation resulting from forest conversion to agricultural land use is an important issue worldwide. This phenomenon is known to influence the activity and size of soil microbial community due to changes in environmental conditions with subsequent losses of soil organic matter (SOM) and soil quality degradation. The objective of this study was to investigate the relationship between soil organic carbon (SOC) losses and enzyme activities following land use conversion from native forests to continuous croplands. The amount of soil microbial biomass carbon (SMBC) and the activity of five soil enzymes (i.e., urease, invertase, alkaline phosphatase, acid phosphatase and arylsulfatase) were measured in croplands derived from forests and adjacent natural forests all on similar soil type at Gorgan site located in Northeast Iran. The content of SMBC decreased (47–83%) with deforestation at both soil sampling depths (0–20 and 20–40 cm). With the exception of phosphatases, the absolute activities of soil enzymes (activity on a soil mass basis) tended to decrease significantly (15–35%) with continuous cultivation. However, the specific enzyme activities expressed either per unit of SOC or SMBC tended to increase (about 1.5–5.5 times) with conversion of forestlands to croplands. The significant positive correlation between enzyme activity per SMBC and C turnover rate may imply that a faster C cycle and loss due to deforestation is related to a greater enzymatic activity by a smaller size of microbial biomass in cropland soils. In brief, the specific activities of soil enzymes could be used to reveal SOM losses and soil degradation in natural forest ecosystems, and to identify changes in soil quality and fertility following deforestation. Changes or improvements in soil management such as cessation of cultivation or implementing agricultural practices that stop or minimize soil disturbance are most likely needed to stop further soil degradation, restore soil quality and rebuild SOC stocks to offset CO_2 emissions in these ecosystems.

1. Introduction

Deforestation as a consequence of changes in socio-economic and environmental conditions is an important issue worldwide (Guo and Gifford, 2002; Dinesh et al., 2004). Conversion of primary forests with a climax community to agricultural lands is often accompanied by changes in plant composition and biomass (Solomon et al., 2002), decreased organic inputs and soil organic carbon (SOC) losses (Golchin and Asgari, 2008; Khormali et al., 2009; Beheshti et al., 2012) and subsequently alterations in soil abiotic factors such as declined moisture, aggregate stability and percent pore space (Golchin and Asgari, 2008; Khormali et al., 2009; Beheshti et al., 2012; Wei et al., 2013). These changes can be reflected by microbial functional capacity, e.g., microbial metabolism, biomass and composition, enzymatic activities and SOC flux, all of which are related to the overall soil quality and function (Dinesh et al., 2004; An et al., 2008; Chaer et al., 2009). The net effect of decreased organic inputs after deforestation would be a loss in soil organic matter (SOM) and low carbon (C) sequestration in the soils over time (Guo and Gifford, 2002; Solomon et al., 2002; Khormali et al., 2009; Beheshti et al., 2012); and ultimately a decline in soil fertility and quality (Dinesh et al., 2004; An et al., 2008; Khormali et al., 2009; Beheshti et al., 2012). When converting forest sites to agricultural soils, significant losses of SOC may occur as a consequence of increased decomposition rate of organic inputs and reduced physical protection of SOM (Ashagrie et al., 2007; Wei et al., 2013).

The activities of soil enzymes and the size of soil microbial biomass are important indicators of microbial and biochemical processes and functions because they are involved in SOM decomposition, C sequestration, nutrient cycling and availability (Sparling, 1997; Dick, 1997; Nannipieri et al., 2002). Soil enzymes

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http://dx.doi.org/10.1016/j.ecolind.2014.11.008
1470-160X/

are a vector for the loss of SOC from ecosystems due to their involvement in SOC dynamics and decomposition processes (Dick, 1997). Soil enzymatic activities and microbial biomass pool have been used as indicators of soil fertility and quality (Dick, 1994, 1997; Sparling, 1997), and have been shown to be affected negatively by land use changes and agricultural practices (Acosta-Martínez et al., 2003; Trasar-Cepeda et al., 2008; An et al., 2008; Chaer et al., 2009; Wang et al., 2012a,b). The measure of soil enzyme activities and microbial biomass size provides integrative information on the biochemical processes in the soil (Paz-Ferreiro and Fu, 2014; Raiesi and Beheshti, 2014) and there has been growing reports that soil enzymes are potential early and sensitive indicators of changes in plant community and soil conditions after deforestation (Dinesh et al., 2004; Chaer et al., 2009; An et al., 2008). In particular, microbial biomass and enzyme activities have been shown to be more sensitive than total SOC to land use changes and ecosystem disturbance (Saggar et al., 2001; Saviozzi et al., 2001; Paz-Ferreiro et al., 2009; Raiesi, 2012). However, the complex functioning of the soil enzymes raises some doubts about the use of enzyme activities as indicators of soil degradation resulted from land use changes (Trasar-Cepeda et al., 2008).

Generally, changes in the activity and stability of soil enzymes, and microbial biomass size are closely related to changes in organic inputs and SOM contents (Deng and Tabatabai, 1997; Nsabimana et al., 2004; Acosta-Martínez et al., 2007; Katsalirou et al., 2010; Song et al., 2012). Enzyme activities can also correlate with the microbial biomass contents (Deng and Tabatabai, 1997; Acosta-Martínez et al., 2003; Katsalirou et al., 2010). It is therefore not possible to establish whether the observed reductions in soil enzyme activities following land use changes are due to the declined SOM and microbial biomass contents in soil or the real difference in enzyme activity (Trasar-Cepeda et al., 2008; Wang et al., 2012b). Expressing enzyme activities per either SOC or soil microbial biomass carbon (SMBC) unit can be used to decouple the changes in soil enzyme activities from the changes in SOC or SMBC contents and to account for differences in SOC and SMBC contents under different land types and agricultural practices (Acosta-Martínez et al., 2003; Trasar-Cepeda et al., 2008; Wang et al., 2012b). Soil enzyme activity per unit of SOC or SMBC changed differently when compared with enzyme activities on a soil mass basis (Trasar-Cepeda et al., 2008; Katsalirou et al., 2010; Wang et al., 2012b). Cropland soils had lower enzyme activity per unit of soil mass, but greater enzyme activities per unit of C (Trasar-Cepeda et al., 2008; Wang et al., 2012b) and SMBC (Katsalirou et al., 2010) than the corresponding uncultivated soils. Katsalirou et al. (2010) reported a greater enzyme activity per SMBC unit concomitant with decreased microbial biomass and enzyme activity per soil mass unit following cultivation of undisturbed soils. In previous studies, a lower SOC level and higher enzyme activity per SOC unit were observed in both cultivated and uncultivated soils (Trasar-Cepeda et al., 2008; Wang et al., 2012b)

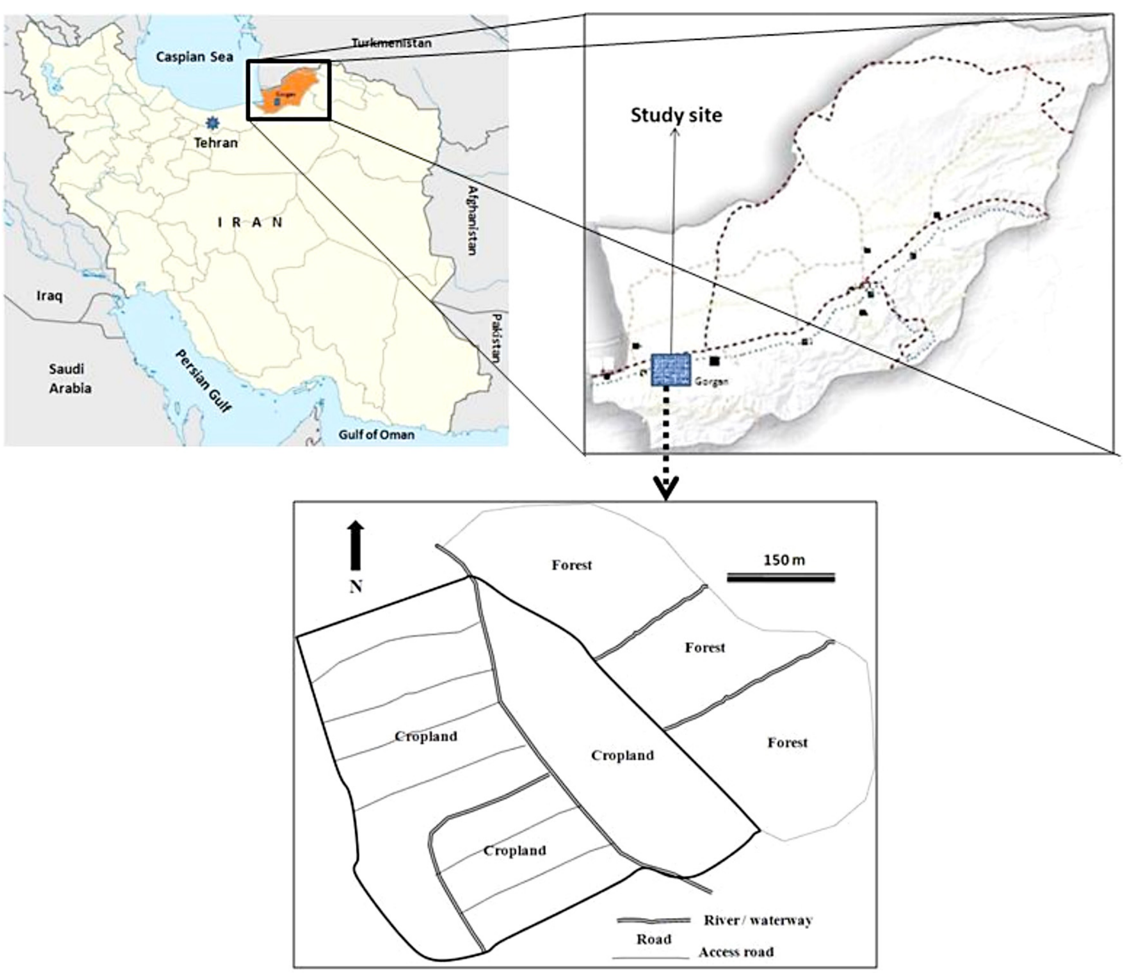

Fig. 1. Map of Golestan province showing the study site, and diagrammatic presentation of the spatial distribution of native forests and adjacent croplands, and the locations of three sampling plots (>3 ha) for each land use. Forests and agricultural fields are spatially separated by waterways or roads.