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Douglas-fir reforestation in North Apennine (Italy): Performance on soil carbon sequestration, nutrients stock and microbial activity

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ABSTRACT

The aim of the study was to determine the effect of mature Douglas fir reforestation (DR) on nutrients and C stocks in mineral soils compared with beech forests (BF) at two altitudes in North Apennine, Italy, at around (1) 1028 and (2) 1281 m a.s.l. To explore the effects of Douglas fir reforestation with respect to natural beech forest, the microbial biomass and its activity were also taken in account as a driving force of organic C mineralization. For each fixed-depth mineral layer (0–5, 5–10 and 10–30 cm) the bulk density values were determined, also estimated using common pedotransfer functions (PTF). Total organic C (TOC) stock in the 0–30 cm layer was determined using both the measured and the PTF-estimated bulk density. The nutrients stocks (C pools, N, P, S, Ca) as well as potential microbial respiration and enzyme activities per centimeter were also calculated for the whole depth. TOC and C pools were positively affected by Douglas fir at 1028 m a.s.l. with respect to the other altitude and trees cover. In DR1 with respect to DR2, BF1 and BF2, double contents of TOC (344 ± 13 *vs.* 157 ± 1, 122 ± 6, $162 \pm 1\ g\ m^{-2}\ cm^{-1}$) and residual C pool ($220 \pm 8$ vs. 65 ± 1, 63 ± 3, $116 \pm 1\ g\ m^{-2}\ cm^{-1}$) were observed. Conversely, P stocks were significantly higher under beech at 1300 m a.s.l. because highest P litter content were found in BF2. Moreover, the activity of enzyme involved in C cycle (SEIc) suggest that to establish the effects on soil organic matter biochemical degradation an interaction between plant cover and altitudes may occur. The fast biochemical degradation of organic matter produced by beech forest and Douglas fir plantation occurred at 1281 and 1028 m a.s.l., respectively (BF1 vs. BF2 = 1.40 vs. 4.35 DF1 vs. DF2 = 2.54 vs. 2.14 mmol MUF $m^{-2}\ h^{-1}\ cm^{-1}$). In conclusion, in the North Apennine (Italy) Douglas fir old reforestation with respect to natural beech forest caused substantial improvement on soil C sequestration, N stock and microbial activity at lower altitudes (1028 m vs. 1281 m a.s.l.). Moreover, to assess soil nutrient stocks, the applicability of PTFs might be improved by the use of soil depth in BD estimation.

1. Introduction

Forest ecosystems are an invaluable resource for biodiversity and environmental sustainability (Anderson, 2003; Lejon et al., 2005). In Europe, in the second half of 1900, the production of high-quality wood has led to a major forests exploitation in which the native deciduous species were replaced with monospecific conifer plantations, often of exotic origin, characterized by high productivity (Lejon et al., 2005). The fear, that exotic species could change the ecosystems, has stimulated the study in the short and long-term of their impact on soil fertility, biological diversity (Herbauts and de Buyl, 1981; Ranger et al., 1990), giving rise to questions about the forest ecosystems functioning (Noirfalise and Vanesse, 1975; Hobbie, 1992 Hobbie, 1992). At the end of 2000, increased concerns were observed for the ecological risks posed by monoculture conifers (Augusto et al., 2002; Rothe et al., 2002) and the studies were addressed to applied to the sustainable forest management maintaining ecosystem functioning (Zerbe, 2002; Janowiak and Webster, 2010).

Douglas-fir played an important role in Italian plantation forestry because, within its optimal vegetation zone ranged from 600 to 1000 m a.s.l., no indigenous conifer has similar characteristics of productivity and timber quality (Corona et al., 1998). The forest management in many areas of the Apennines is failed with the consequent abandonment, no-renewal and degradation of forests. The tendency in Europe is to replace monocultures of

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conifers with native broadleaves, anyhow, a detailed knowledge of the effect of tree species on soil processes is necessary, in order to preserve the ecosystem processes (Malchair and Carnol, 2009).

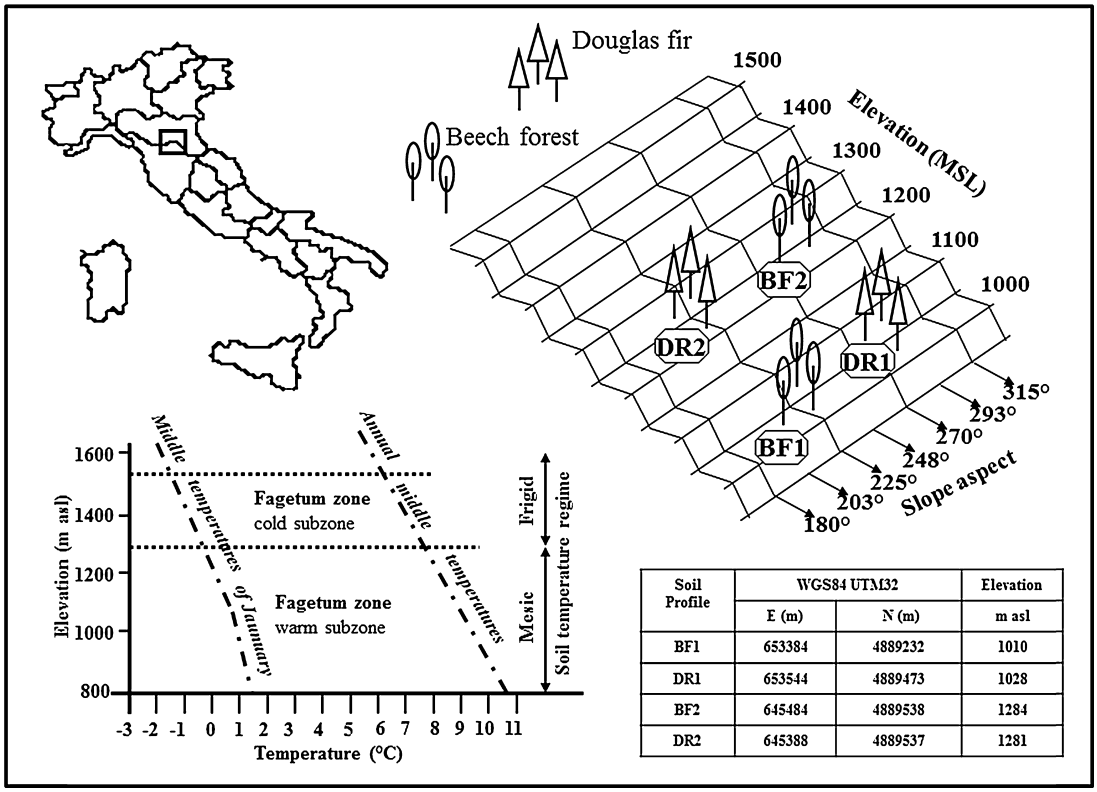
The forest floor, seldom confused with humus, is very important in that it provides a source of food and habitat for myriad micro flora and fauna, whose activity is essential for the maintenance of the nutrient cycles of nitrogen, phosphorous and sulfur.

Generally, coniferous species have often acidified soils, reduced the cycling of nutrients, depressing microbial activity (Vittori Antisari et al., 2010) and these effects are probably partly due to recalcitrant compounds in coniferous needles (Berger et al., 2012), while little information was available for Douglas-fir ecosystems. However, Douglas-fir compared with domestic coniferous species, showed lower acidifying effects on upper soil layers and contributes to better humus forms, recycling nutrients more effectively and producing litter which could be easily decomposed (Kupka et al., 2013). Beech forest (*Fagus sylvatica,* L.) is common in phytoclimatic zone of Fagetum from 900 to 1600 m a.s.l. in North Apennine (Italy) (De Philippis, 1951) as well as Douglas-fir (*Pseudotsuga menziesii* var. *menziesii*) reforestation stands but in a narrow range of elevation, from 600 to 1000 m a.s.l. (Corona et al., 1998). Douglas-fir plantations were performed as recovering of degraded agricultural and forest land, because of fast growth of Douglas-fir and consequent increase of soil organic matter along soil profile. However, the optimum Douglas-fir vegetation zone to obtain high productivity and soil quality improvement has never been tested in the North Apennine (Italy). Moreover, the fear that exotic species could change the ecosystems has stimulated the study in the short and long-term of their impact on soil fertility and nutrient stocks, no expectation was made with respect to soil organic carbon sequestration. In fact, little is known about the effect of this exotic species on nutrients biogeochemical cycle along soil profiles (Welke and Hope, 2005). For this reason, the aim of the study was to determine the effect of Douglas-fir old reforestation across two elevations (1028 and 1281 m a.s.l.) in the North Apennine (Italy), on nutrients and organic C stocks in mineral soils. To explore the effects of Douglas-fir reforestation with respect to natural beech forest, the microbial biomass and its activity were also taken in account as a driving force of organic C mineralization.

2. Materials and methods

2.1. Site description and field survey

The study area is included between 1000–1300 m a.s.l., and it is located in the Corno alle Scale park (Northern Emilia-Tuscany Appenines, Italy). Natural beech forests (*F. sylvatica,* L.) and Douglas-fir (*P. menziesii* Franco) reforestations dominate the Fagetum warm phytoclimatic subzone (below 1300 m a.s.l. according to the Pavari's phytoclimatic classification; De Philippis, 1951). The mean air temperature is 9 °C and the annual precipitation ranges from 1270 mm (weather station in Sestola, 1020 m a.s.l.) to 2100 mm (weather station in Passo Porretta, 1313 m a.s.l.). Soil develop on Cervarola massive sandstone, with particle size from coarse to fine, consisting in a prevailing silica–clastic components such as quartz, feldspar, mica, biotite and chlorite. In the District "Monte Cavallo Corno alle Scale", beech forest (*F. sylvatica* L.) is prevailing and the stands are monospecific. The beech forest is natural pure and the majestic century-old specimens of tall trees are rare, replaced by plants of smaller size for the prevailing coppice management. The minimum cutting cycle is 30 years. However, in this last 50 years the beech forest is abandoned and for this reason the plants have reached heights between 18 and 22 meters and diameters of logs between 160 and 180 cm. Some tree specimens have bigger size, up to 30–35 m tall and trunk diameter of 2 m. The Douglas-fir reforestation is 70 years



Soil Profile	WGS84 UTM32		Elevation
	E (m)	N (m)	m asl
BF1	653384	4889232	1010
DR1	653544	4889473	1028
BF2	645484	4889538	1284
DR2	645388	4889537	1281

Fig. 1. Localization of the survey area and soil sampling scheme.