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Microbiological Pools of Soil Carbon, Nitrogen and Phosphorus under Exotic Tree Plantations in the Degraded Grasslands of Iran

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The aim of current research is to evaluate soil carbon, nitrogen and phosphorus pools, and selected physico-chemical soil properties in a plantation area with 20-year-old exotic tree (*Picea abies* and *Pinus nigra*) species. The study area is degraded grassland of Fandogloo Region, Ardabil Province, Iran. Soil samples were collected at three depths such as 0–15cm, 15–30cm, 20–30cm, and 30–50 cm, and characterized with respect to bulk density, electrical conductivity (EC), pH, texture, organic carbon, total nitrogen, and available phosphorous. The results showed that afforested stands significantly affected on soil characteristics due to piles of soil microbiology. The soil organic carbon (SOC), total nitrogen (TN) and available phosphorus (P) were significantly different among the various stands and depths. The minimum amount of soil carbon sequestration in the degraded grassland was 21.40 Mg ha^{-1}, which had significantly different from afforested stands. The *Pinus nigra* had high significant difference in the amount of TN (2.52 Mg ha^{-1}) from the other stands and degraded grassland (1.75Mg ha^{-1}). The amount of available phosphorus of forest stands compared to degraded grassland did not show a significant increase, while a significant decrease of phosphorus was seen in the mixed *Picea abies* - *Pinus nigra* stand (42.07 kg ha^{-1}) than the degraded grassland (49.27 kg ha^{-1}). The soil surface layer (0-15 cm) had the minimum SOC, TN, and P than the other lower layers which it could be due to high consumption rate in the primary stages of growth to develop biomass. There was a significant positive correlation between the SOC and TN in the all afforested stands. In general, the afforestation with exotic coniferous species in the degraded grassland improved the SOC and TN, but available phosphorus was no significant increase, meanwhile, it shows a decreasing trend in the study area. Finally, this study illustrated that afforestation with exotic coniferous species in degraded grasslands have a positive impact on surface soil properties and the planting of these species might be useful in soil reclamation projects in the semi-humid regions.

Key words : Carbon Sequestration, exotic coniferous, Microbiological stocks, Fandoghloo Region.

Biogeochemical cycles of carbon and nitrogen have been globally drawn attraction in the terrestrial ecosystems in the recent decades. Because emission of their oxide form to the atmosphere had great contribution to the global warming (Fu *et al*, 2010). The afforestation has been determined as one of the most strategies for balancing the global carbon dioxide emissions (Davis and Condron, 2002; Varamesh *et al*, 2014). Soil organic carbon is a complex material and vital part of the soil. It's the primary consisted of soil organic matter (Jaber and Al-Qinna, 2014).

The soil was considered as the main organic carbon pool and more than 75 percent of terrestrial ecosystem carbon pool in the soil and in the global scale, about 4 to 5 times more than organic carbon pool in the living vegetation (Lal, 2004, Jassal, *et al* 2012; Varamesh *et al*, 2014). Restoration of the degraded ecosystems could cause increasing in carbon pool by implementing appropriate land use types (Nosetto *et al*., 2006; Yüksekand Yüksek, 2011; Fataei *et al*, 2013). Giuffre *et al* (2003) reported that there is a significant difference between the afforested

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pines in comparison to grassland areas based on evaluating of the soil organic carbon in the Patagonia region of Argentina. Nosetto *et al* (2006) observed that the afforestation with *Pinus Ponderosa* species in Patagonia region caused an increase in above and below-ground carbon pool. Mireia *et al* (2010) stated that exist a significant increase in the soil organic carbon by means of afforestation with *Pinus halepensis*.

Since, the carbon cycle and nitrogen were strongly linked together, land use changes might result in changes in organic carbon and nitrogen pool (Houghton *et al*., 1999). Therefore, the increase of available soil nitrogen levels could cause a quantitative variety and positive above-ground carbon sequestration (Smith *et al*., 2000; Magnani *et al*., 2007; Liu and Greaver, 2009). Magnani *et al* (2007) found that carbon sequestration clearly linked to the nitrogen sedimentation rate.

Moreover, nitrogen and phosphorus have integral impact on improve of carbon sequestration by soil (Reeder *et al*., 1998). But, Phosphorus was known as an effective factor of plant growth and strength in inappropriate conditions, as well as, low mobility in the soil (Zhao *et al*., 2007). Phosphorus deficiency in the soil could be due to the reduction of biomass growth which it in turn limited carbon sequestration (Bronson *et al*., 2004). Owing to afforestation, the changes in phosphorus were different, so that zhao *et al* (2007) reported phosphorus decrease in the *Pinus sylvestris* afforestation. Meanwhile, Lemma and Olsson (2006) did not observe a significant difference after afforestation with exotic tree species.

Most studies depicted significant changes in soil organic carbon and nitrogen pool, and their distribution (Varamesh *et al*., 2014). However, studies on the effects of mixed and pure plantation of coniferous species considering changes of available phosphorus were drawn less attention. There was no consensus whether the forests were improvers or degraders of the soil or not (Attiwill and Adams, 1993).

As the mentioned above, the comparison of different afforested stands with their adjacent grasslands to understand changes of soil nutrients due to plantation (Davis and Lang, 1991; Farley and Kelly, 2004). Thus, the main objective of this study was to estimate changes in carbon, nitrogen and phosphorus pool linked to the notable soil properties and consideration of the distribution of carbon, nitrogen and phosphorus pool to the depth of 50 cm in the pure *Pinus nigra*, *Picea abies* and mixed *Pinus nigra - Picea abies* stands in the degraded grasslands in Fandoglo region, Ardabil province of Iran.

MATERIALS AND METHODS

Study area

The study area is located in the northwest of Iran (northeast of Ardabil), between latitudes 38° 22' to 38° 24' N,and longitudes 48° 31' to 48° 34' E (Fig. 1). It covers an area about 50 ha. According to Namin Meteorological Station, the mean annual precipitation and temperature were 379 mm and 8.8°C, respectively. The elevation of the forested area ranges of 1,350 to 1,500 m above sea level. The study area including pure *Pinus nigra*, *Picea abies* and mixed *Pinus nigra - Picea abies* stands of afforested area. In the past, afforested areas were barren lands, and were planted by the mentioned species almost 20 years ago. The soil texture of the area is loam and clay loam.

Soil sampling and laboratory analysis

Soil sampling was carried out during the summer time (2013) using a randomly systematic method from six squares (400 m^2) in each type of plantation system, i.e. *Picea abies* and *Pinus nigra*. In order to decrease the bordering effects, surrounding rows of stands were not considered during sampling (Varamesh *et al*., 2014). Four soil profiles were dug in the four corners of the plot, then soil samples were collected at 0-15, 15-30, and 30-50 cm depths using a core (Ø 35 mm) sampler, thus resulting in 72 soil samples for each stand at three different depths. For calculation of the soil Carbon, Nitrogen and Phosphorous storage, bulk density of soil was determined. From the soil pit, bulk density samples were taken from different soil layers (0–50 cm) with a stainless steel cylinder (d = 40 mm and volume=50 cm^3) avoiding compression of the soil and preserving soil structure (Uri *et al*., 2012). Litter was removed from each profile, as well as, large plant material (e.g., root and shoots) occurring in each soil sample. Then, soil samples were air-dried and 2 mm sieved (Lemma, *et al*., 2006).

Dry bulk density was calculated by dividing the oven dry mass at (105 °C) of the <2 mm fraction by the volume of the core. The soil texture was determined by the Bouyoucos hydrometer method (Bouyoucos 1962). Soil pH was determined potentiometrically in a1:2.5 (v/v) soil: water suspension. Electrical conductivity (EC) was characterized with (soil: water ratio, 1 : 2). For testing of total N (Kjeldahl) in the soil samples, Tecator ASN 3,313 was employed. Available phosphorus (ammonium lactate extractable) in the soil was determined by flow injection analysis using Tecator ASTN 9/84 and total organic C determined by the Walkey and Black method.

Calculations of soil total N and available P

The total SOC (Mg ha^{-1}) stock within a certain soil layer was calculated according to the following equation: (Lemma *et al*., 2006)

$$\text{SOC (Mg ha}^{-1}) = \text{SOC (g kg}^{-1}).z.\pi_b.10$$

As well as, total soil N and available P within a soil depth were converted to an area basis (mass ha^{-1}) according to the following equations: (Lemma and Olsson, 2006).

$$\text{Total N(Mg ha}^{-1}) = \text{total N(g kg}^{-1}).z.\pi_b.10$$

$$\text{Available P (kg ha}^{-1}) = \text{P (mg kg}^{-1}).z.\pi_b.10$$

Where, z is soil layer thickness (m), and σb is dry bulk density (Mg m-3).

Statistical analysis

All of data were analyzed using the SPSS 19.0. The variable normality test was checked by the Kolmogorov– Smirnov, meanwhile, Levene's test was used to examine the equality of the variances. Differences in soil characteristics among afforested stands and depths were tested with two-way analysis (ANOVA) using the General Linear Model (GLM) procedure, with different stands (pure *Pinus nigra*, *Picea abies* and mixed *Pinus nigra-Picea abies* stands, and control region) and depths (0–15, 15–30, and 30–50 cm) as independent factors.

Interactions between independent factors were also tested. Duncan's test was used to separate the averages of the dependent variables which were significantly affected by treatment. Significant differences among treatment averages for different parameters were tested at $P \leq 0.05$.

RESULTS

The texture, pH and EC results are presented in the Table 1. The differences in the percentages of sand, silt and clay are apparent in this stand. But these differences are not significant. Accordingly, the large amount of sand percentage in the degraded grassland, the highest amount of slit in the *P. Nigra* stand and there is

Table 1. Soil textural, pH and EC analysis under the different tree species and grassland

System	Depth	Texture (%)			pH_{H2o}	EC
	(cm)	sand	silt	clay		(dS m^{-1})
Grassland ("degraded")	0-15	40.33	36	23.67	5.53	0.02
	15-30	44.33	34.67	21	5.72	0.03
	30-50	38	39.67	22.33	5.71	0.03
Pinus nigra	0-15	25.67	42.33	32	5.63	0.02
	15-30	29.67	41.67	28.67	5.65	0.03
	30-50	29.67	38.67	31.67	5.5	0.02
Picea abies	0-15	33.42	38.42	28.17	5.49	0.03
	15-30	33.75	37.58	28.67	5.54	0.03
	30-50	32.92	36.75	30.33	5.59	0.03
P. abies- P.nigra	0-15	26.33	42.67	31	5.51	0.02
	15-30	29	39.33	31.67	5.45	0.02
	30-50	29.33	36.67	34	5.61	0.01

Values are means of triplicate soil analysis the highest percentage of clay in the mixed *p. abies-P.nigra* stand. The pH values did not show significant differences in the all stands studied. The EC showed trace amounts in the all stands.

The bulk density and C: N ratio in each stand is given in the Table 2. The results show that the C: N ratio in the grassland (control) and *Picea abies* stand have no significant differences in the various soil layers. The highest C: N ratio was observed in the pure *Pinus nigra* and the mixed *P.abies-P.nigra* stands in the middle depth (15-30cm) and there is the lowest ratio in the lower depth of both stands (30-50 cm). In the other word, the similar trend in the C: N ratio was observed in the two stands. Bulk density shows an increasing trend with the increase of depth in the all stands except mixed *P.abies-P.nigra*.

Two-way analyses of variance (two-way ANOVA) show that the impacts of stands and depth have a significant effect on the soil organic carbon, total nitrogen and available phosphorus (Table 3).

The highest soil organic carbon was observed in the *Pinus nigra* stand (28.57 Mg ha^{-1}) coupled with mixed *P. abies-P.nigra* (27.45 Mg ha^{-1}) and pure *Picea abies* stands (25.43 Mg ha^{-1}) have no significant difference (Fig.2a). The minimum amount of soil organic carbon is in the degraded grassland stand (21.40 Mg ha^{-1}), which is significantly different from the afforested stands.

Table 2. Soil ρ_d and C:N ratio (mean ±S.E.) up to 50 cm depth under the tree plantations and the Grasslands (control)

Depth	Stands							
(cm)	*Pinus nigra*		*Picea abies*		*Picea- Pinus*		Grasslands (control)	
	ρ_d	C:N	ρ_d	C:N	ρ_d	C:N	ρ_d	C:N
0-15	1.44±0.003^c	12.58±0.52^b	1.48±0.02^b	13.46±0.53^a	1.41±0.003^b	14.23±0.38^b	1.37±0.041^b	13.83±1.36^a
15-30	1.51±0.003^b	15.96±0.04^a	1.54±0.03^{ab}	14.44±0.48^a	1.31±0.006^c	15.90±0.05^a	1.50±0.044^{ab}	12.20±2.50^a
30-50	1.61±0.009^a	8.58±0.29^c	1.59±0.03^a	12.76±0.89^a	1.53±0.003^a	12.83±0.08^c	1.57±0.050^a	12.13±0.97^a

Values followed by the same letter within a column are not statistically different (Duncan, $P < 0.05$).

Table 3. Results of two-way ANOVA for the effect of Stands and soil depth on soil organic carbon, total nitrogen and available P distribution

source	df	Organic C		Total N		Available P	
		F	*P*	*F*	*P*	*F*	*P*
Stands	3	4.43	<0.01	5.88	<0.01	6.24	<0.01
Soil depth	2	4.96	< 0.05	17.06	<0.001	38.89	<0.001
stands× Soil depth	6	4.62	< 0.05	5.45	<0.001	2.87	<0.01

F and *P* values, from two-way ANOVA are given. All values show significance at $P < 0.05$. df is Degrees of freedom.

The Pure *Pinus nigra* stand show the highest TN (2.52 Mg ha^{-1}) which is significantly different from the *P.abies-P.nigra* (1.95 Mg ha^{-1}), *Picea abies* (1.88Mg ha^{-1}) and degraded grassland (1.75Mg ha^{-1}) (Fig.2b). the available phosphorus was the highest in the *Picea abies* (52.18 kg ha^{-1}) which this amount show no significant difference with degraded grassland (49.27 kg ha^{-1}), but it has significant differences with *Pinus nigra* (45.42 kg ha^{-1}) and mixed *P. abies-P.nigra* stands(42.07 kg ha^{-1}) (Fig.2c).

The results depict that the distribution of soil organic carbon, total nitrogen and available phosphorus among the different stands and depths of soil layers are significantly different (Table 3). Accordingly, the highest amount of soil organic carbon was in the *Pinus nigra* stand and lower depth (30-50 cm) (33.23 Mg ha^{-1}) and the amount in the middle depth (30-15 cm) was not significantly different (28.98 Mg ha^{-1}).

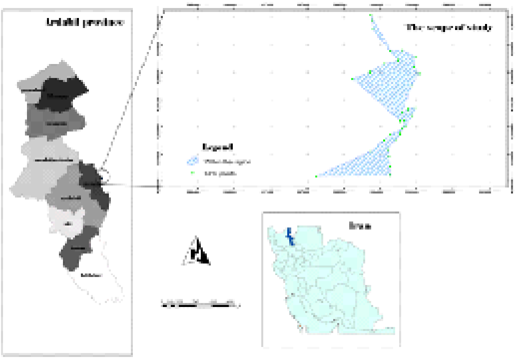

Fig. 1. Location of study area (Fandogloo region in Ardabil province, Iran)

The mixed *P. abies-P.nigra* stand in the middle depth having the carbon pool of 131.48 Mg ha^{-1} does not show significant difference with the pure *Picea abies* and *Pinus nigra* stands. The minimum amount of soil organic carbon in the degraded grassland was observed in the all three depths (21.41, 20.26, 22.53 Mg ha^{-1}). Although, there are differences among the stands, there was no statistically significant difference in the first depth. In the middle depth (15-30 cm), the highest amount was detected in the *Pinus nigra* (28.98 Mg ha^{-1}) and lowest in the degraded grassland (20.26 Mg ha^{-1}), they have no significant

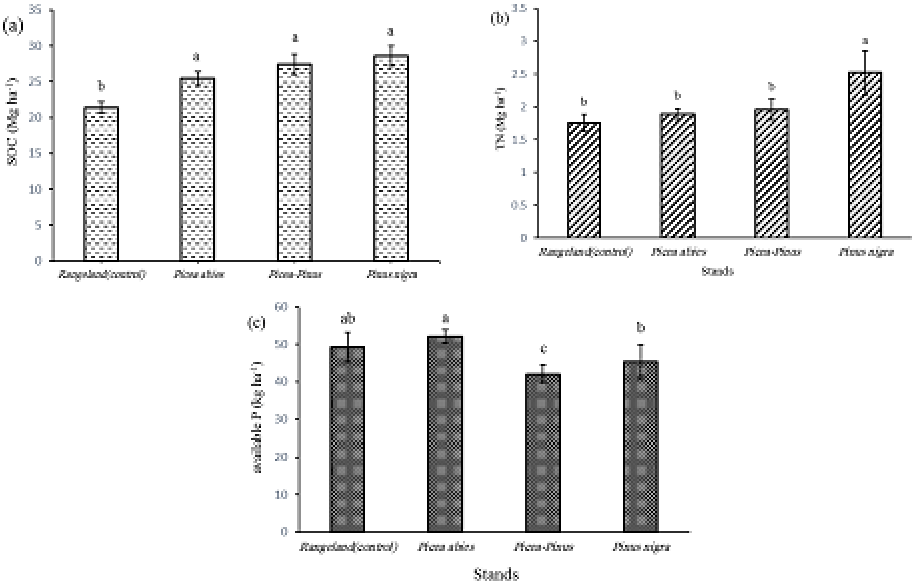

Fig. 2. Mean (±S.E.) of SOC, TN (Mg ha^{-1}) and available P (kg ha^{-1}) within 0-50 cm depth under different stand. Different letters denote significant differences at $p < 0.05$

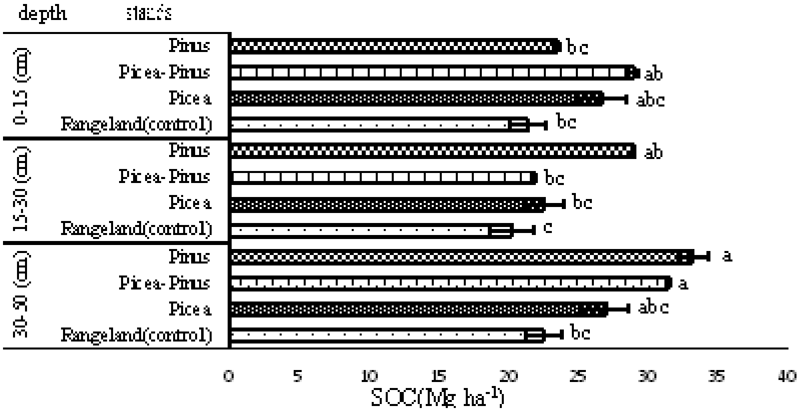

Fig. 3. Mean (±S.E.) of total SOC (Mg ha-1) within 0–15, 15-30 and 30-50 cm depth under different stand . Different letters denote significant differences at $p < 0.05$.

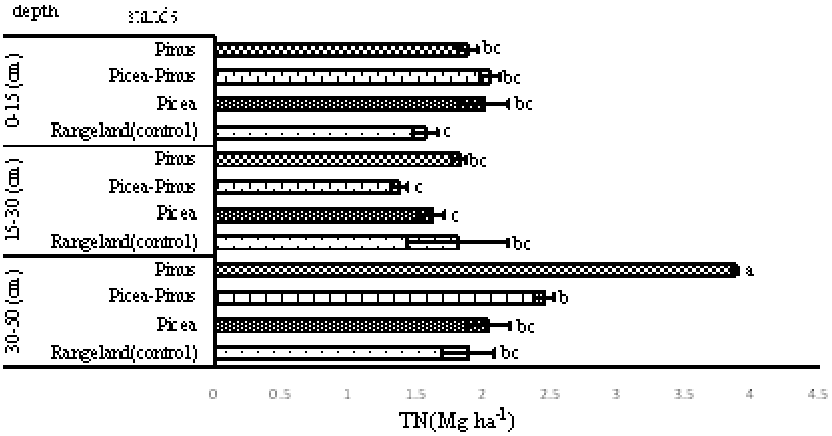

Fig. 4. Mean (±S.E.) of total N (Mg ha^{-1}) within 0–15, 15-30 and 30-50 cm depth under different stands. Different letters denote significant differences at $p < 0.05$

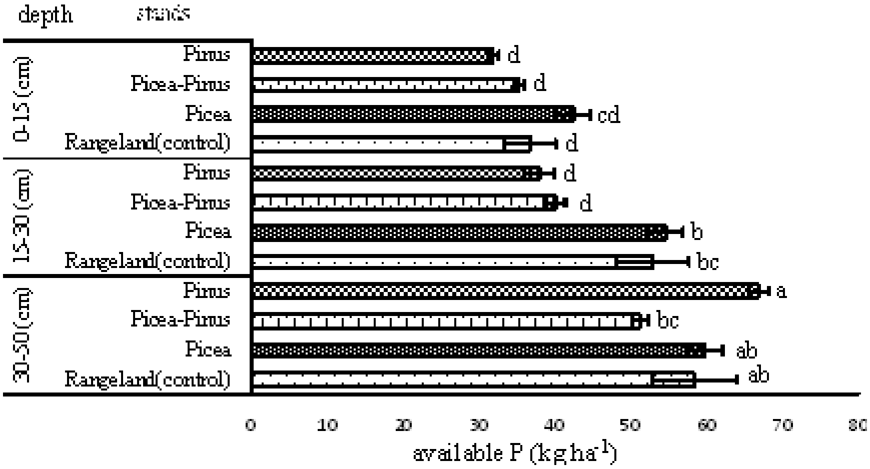

Fig 5 Mean (±S.E.) of available P (kg ha^{-1}) within 0–15, 15-30 and 30-50 cm depth under different stands. Different letters denote significant differences at $p < 0.05$

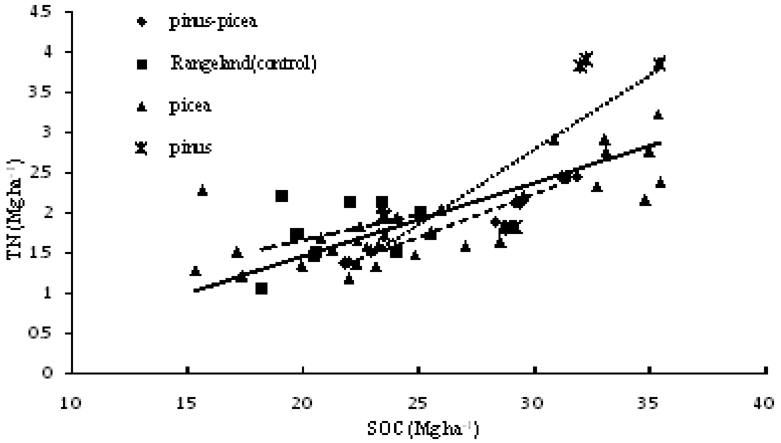

Fig. 6. Correlation between SOC (Mg ha^{-1}) and total N (Mg ha^{-1}): *picea* ($r^2 = 0.54$, $p < 0.05$), *pinus* ($r^2 = 0.62$, $p < 0.05$), *pinus-picea* ($r^2 = 0.97$, $p < 0.05$) and Grassland($r^2 = 0.14$),. All are significant except Grassland(control).

differences with each other.

According to Table 1, the distribution of total nitrogen among stands and depths show significant differences. The highest amount of TN was observed in the lower depth (50-30 cm), and in the *Pinus nigra* (3.87 Mg ha^{-1}) which is significantly different from other stands and degraded grassland. The lowest amount of TN was seen in this depth of degraded grassland (1.88 Mg ha^{-1}). In the middle depth (30-15 cm), there is no significant difference between stands and degraded grassland. In the upper depth (0-15 cm), the lowest TN (1.56 Mg ha^{-1}) was seen in the degraded grassland, but this amount is significantly different from afforestrated stands.

The distribution of available P pool among different stands and depth show significant differences (Table 1). The highest amount of available P was observed in the *Pinus nigra* (66.69 kg ha^{-1}) and the lower depth (50-30 cm) which it was significantly different from *P. abies-P.nigra* (51.11 kg ha^{-1}), in this depth it does not show significant difference from other stands. In the upper layer (0-15 cm), there was no significant difference in the amount of available P. In the middle depth (15-30 cm), the high available P was seen in the *picea abies* (54.5 kg ha^{-1}) which show no significant difference from the degraded grassland (52.86 kg ha^{-1}).

DISCUSSION

Afforestation of fast-growing tree species in the degraded grassland caused to changes in the amount of soil organic C, nitrogen and P pool. In other words, effects of coniferous species and soil layers and their interactions had significant impacts on the amount of organic C, TN, and available P (Table 1). These results were consistent with findings of Zhage *et al* (2013). They observed that the land use and the soil depth had significant impact on the distribution of soil organic carbon and total nitrogen. Hansson *et al* (2013) examined the C and N pool in the biomass and soil of three adjacent *Picea abies* and *Pinus sylvestris*, *Betula pendula*, and *Betula pubescens* 50 years old stands. The results showed that there were significant difference in the terms of C and N pool in the biomass and soil. In this study, the *Picea abies* showed higher amounts of carbon and nitrogen pool in the soil. Our investigation also presented that the *Picea abies* and *Pinus nigra* was not significantly different, although the numerical value of the *Pinus nigra* showed higher than *Picea abies* (Approximately, 3.14 Mg ha^{-1} greater than the *Picea abies*). Ross *et al* (1999) examined the changes in soil organic carbon, nitrogen and phosphorus pool in the three adjacent ecosystems (grassland, forest, and coniferous *pinus radiate* stand) in New Zealand which it did not indicate significant changes in the pool and distribution of C, N and P in the soil profile. Results of this study also noted depth impact on the amount of carbon pool, nitrogen and phosphorus. Therefore, SOC pool had become higher in the lower depth (30-50 cm) of the *Pinus nigra* compared to the surface and middle depths (14.46 and 41.28 percent, respectively), and in the mixed *P. abies-P. nigra* were 8.63% and 43.94% and in the *P. abies* stand were 1.24% and 19.36%, respectively.

Also, N pool in the lower depth of the *P. nigra* stand showed an increase compared to surface and middle depths which were 106.95 and 113.81 percent, respectively, and in the mixed *P. abies-P. nigra* were 20.09 and 78.83 percent, respectively. Whereas in the *P. abies* stand were 22.40 and 01.06 percent, respectively. Available P pool increased in the lower depth (30-50 cm) in *P. nigra* stands relative to the surface and middle depths (110.04 and 76.24 percent, respectively) and in the mixed *P. abies-P. nigra* were 45.36, and 27.93 percent, respectively, and in the *P. abies* stand were 41.11, 9.57 percent, respectively.

This study indicated that the tree species had direct impact on the C, N and P pool. Lemma *et al* (2006) showed with similar management history of *Cupressus lusitanica* and *Pinus patula*, however, according to the tree species, there was significant difference in the amount of soil organic carbon. Lemenih *et al*. (2004) examined the variation of soil properties on the *Cupressus lusitanica* and *Eucalyptus saligna* species, and they concluded that the extent and direction of changes in the soil properties depended on the tree species.

The basic assumption of this comparative study was the similarity of the soil between the planted tree stands and grassland site (control).

Accordingly, the results indicated a significant increase in the organic C pool in the planted stands (Fig 2a). In the other word, after 20 years of conversion of grassland into afforestation, the increase percentage of the soil organic C in the pure *P.nigra*, the mixed *P. abies-P. nigra*, and the pure *P.abies* stands were 22.28%, 5.33%, and 83/ 18 %, respectively.

The high amount of organic C pool in the *P.nigra* stand could be obtained by the litter volume produced by this stand. Binkley and Giardina (1998) reported that tree species had different effects on the soil using several mechanisms, including of the inputs, outputs and nutrient cycling. Singh and Singh (1993) believed that accumulation of organic C and nutrients in the different depths of the soil depended on the humus content, canopy area and tree species types. Also, Rice (2000) introduced litter as the most important source of soil organic matter and nutrients.

In this study, different distributions of soil organic C were studied in the different soil layers of the stands considered. An increasing trend was apparent with the increase of depth in the soil organic C pool in the pure *P.nigra* stand, but the two other stands and degraded grassland did not have certain trend (Fig 3). Due to the significant increase in the bulk density in this stand, with the increase of depth (Table 2) and high significant correlation ($R^2 = 0.95$, $P < 0.01$) between soil bulk density and soil organic C pool could be cited as a factor influencing such a trend.

According to the mentioned results, there was higher amount of C pool in the three stands and the grassland site in the lower depth (30-50 cm) than the two upper depths which it could be due to the high bulk density in the lower depth of stands and grassland sites (Table 2). The climatic conditions, plant and tree species, and bulk density of soil were factors influenced the soil organic C pool (Paul *et al*, 2002; Singh *et al*, 2003).

Also, this presumption could be raised that the decomposition process of organic matter was high by micro-organisms in soil depth so that the respiratory rate (emitting CO_2) was high which it in turn decreased carbon sequestration in the superficial layers. Uri *et al* (2012) noted that the high fertility of the soil in the surface layer (0-30 cm) and increase of respiration intense caused decrease in the organic C of soil (29-38% of total carbon).

Similarly, such a trend was seen in the nitrogen pool and available phosphorus. Another possibility was the rapid consumption of elements due to their high demand in the primary stage of growth. Turner and Kelly (1985) also observed such a trend after afforestation with the *Pinus radiata*. They believed that nutrient changes during the 10 to 20 years owing to the rapid absorption of elements in the surface layer of the root and canopy growth. The important point regarding the study of soil organic C was the low amount of soil organic C pool in the degraded grassland of three depths than planted stands.

Significant changes in the total nitrogen among stands and grassland sites, as well as, their different distributions represented the different effects of tree species and the depth of the soil layer on the total nitrogen changes in this study (Table 3, Figures 2b, 4). As compared to the grassland site (as a control), total nitrogen has increased to 43.87 percent in the *p. nigra*, 11.62 percent in the *P. abies-P. nigra,* and 7.61 percent in the pure *P. abies* over the 20 years of afforestation (Fig 2b).

Moreover, significant increase in the total nitrogen pool in the *p. nigra* stands could be due to more production of litter according to larger canopy coverage. The litter production and the degradation rate had significant effect on the soil fertility (Pragasan and Parthasaratly, 2005) and it was an important factor by which tree species affected nitrogen and soil organic matter (Finzi *et al*, 1998).

Meanwhile, several studies were reported on the tree species influencing soil nitrogen, but wang *et al*. (2010) did not observed any differences in soil nitrogen of studied species. Siddique *et al*. (2008) reported that afforested tree species effects on the soil nitrogen differently. Similar results regarding the impacts of tree species on the total nitrogen were obtained by Fröberg *et al* (2011), Hansson *et al* (2011), and Olsson *et al* (2012).

Our results also suggested the impact of exotic coniferous on the total nitrogen of the soil. The high accumulation of nitrogen was observed in the lower depth (30-50 cm) of three afforested stands possessed totally higher means than grassland site in the both surface and lower depths. Lemma and olsson (2006) detected such a trend in their studies on the *Pinus patula* species.

They examined the distribution of N´^{15} in the soil profile which was normally used for studies of soil nitrogen cycle processes (Robinson, 2001) and observed that N´^{15} rate increased with the increase of depth.

Only, middle depth in the grassland site showed higher N than the *P. abies* and *P. abies-P. nigra* stands (Fig 4). The reason for this happening could be due to leaching of this element in the surface layer of degraded grassland site which it was produced in the extended root because of herbaceous plants and other plants, and was leached to the middle depth.

Increase of C: N ratio could be due to the effect of organic matter addition because of tree plantation to the soil in the middle layer of the *P. nigra* and *P. abies-P. nigra* stands compared to grassland sites (as a control) (Table 2). Lemma *et al* (2006) observe the same trend in the C: N ratio of the *P. abies* and grassland site.

Magnani *et al* (2007) emphasized that the pure carbon sequestration in the temperate and boreal forests were clearly associated with levels of nitrogen sedimentation. Murty *et al* (2002) expressed that there is high correlation between carbon and nitrogen decrease, generally. In this study, observe a significant positive correlations between soil organic C and total nitrogen pool in the all tree stands (Fig 6). Lemma *et al* (2006) stated that the N sedimentation or its decrease was closely related to carbon dynamic.

The results showed that not only the amount of available phosphorus in the afforested stands than grassland sites (as a control) did not show significant increases, but also a significant decrease was seen in the *P. abies-P. nigra* stand (Fig 2c). In the short term, biological processes could lead to changes in the distribution of available P (Cross and Schlesinger, 1995). The soil organic P was an important source of available phosphorus (Turner *et al.*, 2003). Microbial activity and phosphates activities caused mineralization of soil organic P (Magid *et al.*, 1996; Richardson, 1994) and resulted in a decrease.

It is likely that afforestation of degraded grassland caused an increase in microbial population which it resulted in a decrease in available phosphorus in the afforested stands. Zhao *et al* (2007) also found similar results declaring the fact that due to the conversion of forests to grassland *Pinus sylvestris* a significant decrease occurred in the soil P pool, especially in the primary steps. They cited the reason of pool reduction in the soil due to high P extraction and slow P recycling.

The mineralization of soil organic P was seen with increase of the microbial activity and phosphatase activities in the studies on the *Picea abies* (Firsching and Claassen, 1996) *Cunninghamia lanceolata* (Chen, 2003) and *Pinus radiata* (Chen *et al*., 2002).

Different distributions of C pool in the different levels of soil layers presented lower amount in the upper layer than the others. As increasing trend in the amount of available P pool in the all stands and grassland site (Fig 5).

CONCLUSION

Our results clearly showed that conversion of degraded grassland into the afforested stands with coniferous trees in the study area considered had the potential to increase the atmospheric carbon sequestration and total nitrogen pool. In this study, it was found that the amount of soil organic carbon and total nitrogen were affected by the planted tree species. This matter should be considered in the next afforestation projects.

The soil profile had different impact on the distribution of soil carbon sequestration and total nitrogen. A high correlation was observed between the amount of soil organic carbon and total nitrogen. Therefore, the nitrogen was introduced as an integral factor in improving and correction of carbon sequestration in the afforested stands.

The amount of phosphorus showed no significant increase during 20 years of grassland conversion to afforestation, and decrease of P in some stands indicated the differences of tree species cultivated on the P pool. In totally, the stand type and total amount of nitrogen and phosphorus reduction related to the tree species must be considered in the conversion management to afforestation in order to achieve manufacturing based on the Kyoto Protocol.

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