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Conversion of Hyrcanian degraded forests to plantations: Effects on soil C and N stocks

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ABSTRACT

Hyrcanian forest ecosystem is considered to be one of the most important natural deciduous forests in the world. Today, these forests are being devastated by human activities. So there have been many plantation establishments with endemic species in degraded forests of this area. But the effects of such conversions on soil C and N stocks and nutrients are still unknown. We investigated the effects of conversion of a degraded natural forest to Alnus subcordata .L, Acer velutinum .Boiss and Cupressus sempervirens. var.horizontalis plantations on soil C and N stocks and nutrients after 18 years. The studied stands are located in the county of Chamestan in the province of Mazandaran, Iran. Some of soil chemical and physical properties including available nutrient concentrations (Ca, Mg, P and K) and total N and organic C stocks in the soil were determined in three soil depths (0-15 cm, 15-30 cm and 30-50 cm). Soil available nutrients were higher under plantation stands compared to the degraded natural forest except for soil available K which decreased under A. subcordata plantation. We expect increasing the soil nutrient improvement with increasing the age of plantation stands. A. velutinum and C. sempervirens had increased soil C and N stocks but A. subcordata decreased soil C stock and increased soil N stock in comparison to the degraded natural forest. These results indicate that conversion of degraded forests with appropriate species can significantly improve soil C stocks, helping to mitigate the negative impacts of the greenhouse effect.

Keywords: *Acer velutinum* .Boiss, *Alnus subcordata* .L, climate change mitigation, *Cupressus sempervirens.* var.horizontalis, soil nutrients.

INTRODUCTION

Hyrcanian forest ecosystem is considered to be one of the last remnants of natural deciduous forests in the world. In comparison to European broad-leaved forests, the Hyrcanian forests seem to have remained from the Tertiary and to be relic ecosystem [43].

In Iran, Hyrcanian (Caspian) forests are located at green strip extending over the Northern Slops of Alborz range of mountains and Southern coasts of the Caspian Sea. This zone has a total area of 1.84 million ha comprising 15% of the total Iranian forests and 1.1% of the country's area [27]. These forests stretch out from sea level up to an altitude of 2800 m and encompass different forest types [44].

Original old-growth northern forests of Iran are essential sources of genetic variation, biodiversity, commercial woody products, and various environmental services (e.g., ground water reservation, auxiliary forest products provision, wildlife habitation, and erosion control) [39]. The presence of approximately 146 native woody species, some of which are ecologically endemic [45], the diverse range of climatic conditions over the approximately 900 × 70 km2 of horizontal/vertical forest expansion, and extensive wildlife habitat, highlight the importance of the original northern forests of Iran [39]. *Fagus orientalis* (Oriental Beech), *Carpinus betulus* (European hornpean), *Acer velutinum* (Velvet Maple), *Quercus castaneifolia* (Caucasian Oak), *Acer cappadocicum* (Cappadocian Maple), *Alnus subcordata* (Alder), and *Tilia platyphyllos* (Large-leaved Linden) are the most important tree species in these forests [46]. Also these forests support such important species like *Prunus divaricata* (Cherry Plum)**,** *Pterocarya fraxinifolia* (Caucasian Wingnut), *Buxus hyrcana* (Boxwood), *Platanus orientalis* (Oriental plane), *Zelkova carpinifolia* (Caucasian Zelkova), *Ulmus campestris* (Field Elm), *Celtis australis* (Lote tree), *Morus alba* (White Mulberry), *Robinia pseudoacacia* (Black Locust), *Populus caspica* (Poplar), *Albizia julibrissin* (Persian Silk tree), *Taxus baccata* (European Yew), *Cupressus sempervirens* (Tuscan Cypress) etc. [44].

Today, these forests are depleting rapidly due to population growth, and associated socio-economic problems, industrial development, urbanism, and more recently intensive/irregular tourism [39]. About 60% of Hyrcanian forests are managed for timber production and the remainders are degraded to varying degrees [46]. The existence of different land-uses, and their increasing alteration, mainly by local communities, mismanagement of natural resources over long periods of time, plans for industrial development (e.g., establishment of industrial towns adjacent to the forested areas), public road construction without detailed environmental considerations and shortage of human/financial resources for sustainable monitoring and management of the forest resources are threatening the existence of the Caspian forests [39].

What is obvious is that the natural forests have been under continuous degradation over the last few decades in this area and there is an urgent need to maintain the functions of this unique forest ecosystem. So National forest management officials have acknowledged this fact and have initiated actions for sustainable management of the Caspian Forests, Different forms of management schemes are planned for implementation, such as documenting and exhibiting the forest disturbance and supervision and management of the remaining natural forest ecosystems in the region [39]. Agricultural abandonment and tree planting for commercial or restoration purposes are also two main methods for the forest restoration [16, 41, 11]. So there were many plantations with endemic and exotic species in degraded forest areas which certainly had many effects on ecosystem specifically on soil fertility and nutrients.

Forest plantations were introduced to supply fuel-wood, charcoal, fodder, sticks and building materials. They were also planted to restore degraded lands, to control soil erosion or to serve as buffer zones around roads and areas of natural forests [15, 19, 24 34]. Although the area of forest plantations has increased, there has been concern over their ecological and environmental effects. It is believed that: they sustain a low diversity of wildlife; they are high consumers of water and nutrients, and increase soil acidification [10, 24]. This has led to studies of soil properties under forest plantations in comparison to natural forests, pastures, natural savannas and croplands all over the world [29, 57, 19, 25, 34, 53]. Hitherto, considerable researches have been carried out concerning species influence on soils in Hyrcanian forests of Iran, but results are not consistent and generalizations are not possible and also most of these researches are not published in English language. Also there are no researches focusing on effects of forest plantations on soil C and N stocks in comparison to natural forests or degraded forests in Northern forests of Iran. Therefore, this study intended to fill this gap by focusing on soil attributes under similar environmental and soil conditions, 18 years after conversion of a degraded natural forest to three species plantations. These species selected among the endemic and most used by foresters in North of Iran.

MATERIALS AND METHODS

2.1. Study area

The study area is located at the Chamestan region in Mazandaran province, on the northern of Iran (36°29' N, 52°7' E). Study stands were located at an altitude of 90 m above sea level and with low slope (0-5%). Annual rainfall averages 803 mm, with wetter months occurring between September and February, and a dry season from April to August monthly rainfall usually averages < 40 mm for 4 months. Average daily temperatures ranges from 11.7 °C in February to 29.5 °C in August. The soils have the textures of loam and clay loam with an acidic pH in top layers and in deep layers soil textures were clay and silty clay and soil pH was less acidic.

Previously this area was dominated by degraded natural forests containing native tree species such as *Quercus castaneifolia*, *Zelkova carpinifolia*, *Parrotia persica*, *Carpinus betulus*, *Diospyros lotus* and *Buxus hyrcana*. But 18 years ago after clear cutting (in small areas in degraded natural forests), reforestations has been established (with 2×2 m spaces) in this area with three species including: *Alnus subcordata* .L, *Acer velutinum* .Boiss and *Cupressus sempervirens.* var.horizontalis [3].

2.2. Sampling method

For investigate the effect of Conversion of degraded natural forests to plantations on soil carbon and nutrients, four experimental sites were chosen in Chamestan region of Hyrcanian forests in Northern Iran. Three plantation stands including: *Alnus subcordata* .L (AS), *Acer velutinum* .Boiss (AV) and *Cupressus sempervirens.* var.horizontalis (CSH) and one degraded natural stand of *Quercus-Zelkova* (DNS), each with area of 10 ha.

At any stands four 5×5 m plots with randomly systematic statistical method selected and in each plot the soils were samples in three depths: 0-15 cm, 15-30 cm and 30-50 cm, after removing the litters. To minimize the inaccuracy, one additional combined sampling was implemented: the soil samples of the four corners of each plot were picked and then these samples were mixed together. So then in every stand for each depth totally ten samples were collected [33, 32, 37, 30, 20].

2.3. Laboratory Methods

After air drying, soil samples were passed through a 2.0 mm (20 mesh) sieve to remove roots prior to chemical analyses. Then, Soil pH was determined using an Orion Ionalyzer Model 901 pH meter in a 1:2.5, soil: water solution. EC (electrical conductivity) was determined using an Orion Ionalyzer Model 901 EC meter in a 1:2.5, soil: water solution. The soil texture was determined by Bouyoucos hydrometer method [7]. The bulk density (g/cm^3) was studied with volumetrically [6]. Soil organic matter was determined using the Walkley-Black method [1]. Total N was determined using the Kjeldhal method [9]. Available P was determined with spectrophotometer by using Olsen method [21]. Available K, Ca and Mg (by ammonium acetate extraction at pH 9) were determined with Atomic absorption Spectrophotometer [8].

The averages of soil bulk density, C and N concentrations were used in this study. The total stocks (C_t, g cm^{-2}) of soil organic C and total N were calculated as following [17, 12]:

$$C_t = BD \times C \times D$$

Where BD is the soil bulk density (g cm^{-3}), C the soil organic C and total N concentration (%), and D is the soil sampling depth (cm).

2.4. Data analysis

The data obtained have been statistically analyzed using the SPSS 17 software. The normality of data examined with Kolomogorov-Smirnov test and the homogeny of variances was investigated by Levene test. Attending to the normality and variance homogeny of data, Two-way analyses of variance (ANOVA) were used to compare soil properties among experimental sites. Duncan tests were used to separate the means of dependent variables. Pearson correlation was used to assess the correlation between soil properties across all studied stands.

RESULTS

3.1. Soil attributes

Particle size of all three depths considered were significantly different ($p < 0.05$) between stands except for the silt and clay fractions of the 0-15 cm soil layer and the sand fractions of the 15-30 cm soil layer. The soil under the degraded natural stand (DNS) had higher clay and lowest sand fractions than the soils of the plantations (Table 1). This may be attributed to the effects of planting practices and associated disturbance on the soils of the plantations. Several other studies conducted on a similar soil as the soil of our study site have reported rapid alteration of stable soil properties including particle size distributions within relatively short periods when subject to deforestation and subsequent cultivation and plantation.

In the 0-15 cm soil layer, Bulk density (g/cm^3) did not differ significantly between degraded natural stand (DNS) and *A. subcordata* (AS), *A. velutinum* (AV) and *C. sempervirens* (CSH) plantations. But in the two other soil depths it was significantly different ($p < 0.05$) between the stands (Table 1). In the depth of 15-30 cm the soil under the CHS stand had highest Bulk density and in the 30-50 cm soil layer the AV stand had highest Bulk density.

Soil pH and EC of all three depths (0-15, 15-30 and 30-50 cm) differed significantly ($p < 0.001$) between DNS and plantations. Soil pH was lowest under DNS in all three soil layers and AV had highest soil EC (Table 2). As it is seen in table 2, plantation with *A. velutinum* and *C. sempervirens* significantly increased soil EC in compared to the degraded natural stand. Soil organic C and total N in the depths of the 0-15 and 15-30 cm were significantly different ($p < 0.05$) between degraded natural stand and plantation stands. But there were no significant differences in soil organic carbon and total N in the 30-50 soil layer. Therefore, it can be said that conversion of degraded natural forest to plantations partly had improved soil C and N contents. Also C:N ratio differed significantly ($p < 0.05$) between stands in two top layer of soil and the degraded natural stand had higher ratio than the plantation stands (Table 2). As can be observed in the results that shown in table 2, conversion of degraded forest to plantations had significantly improved soil available nutrients (P, Ca, Mg and K). Plantations had significantly ($p < 0.05$) increased soil available P in the top 0-15 layer of soil. But in two other soil depths the changes was not significantly different. Available Ca and Mg were significantly ($p < 0.001$) higher under AS than under DNS, AV and CSH in all three soil layers. Also DNS had the lowest amount of available Ca and Mg compared to the plantation stands in all three considered depths. Available K also was significantly different between the studied stands. In all three soil layer AS had the lowest amount of available K than the other studied stands (Table 2). So it can be said that the conversion of degraded natural stand to *A. subcordata* (AS) plantation had negative effects on soil available K 18 years after the conversion.

Table 1- Soil physical properties in the degraded natural stand and plantations in three soil layers with their standard error (below)

	Depth (cm)	DNS	AV	AS	CSH	ANOVA[a]
Silt (%)	0-15	48 a (9.66)	44.5 a (7.84)	49 a (2.88)	40.5 a (2.5)	ns
	15-30	33.5 b (3.5)	40 ab (4.69)	49 a (2.69)	35.5 b (2.06)	*
	3-50	35 b (3.69)	37.5 ab (4.78)	49.5 a (4.78)	30.5 b (2.21)	*
Sand (%)	0-15	20.5 b (3.4)	33 a (2.88)	24.5 ab (4.03)	28.5 ab (2.21)	*
	15-30	17.5 a (2.5)	25 a (4.79)	20.5 a (4.57)	25 a (1.91)	ns
	3-50	16.5 b (2.06)	26.5 a (2.06)	17 b (2.64)	28 a (1.82)	*
Clay (%)	0-15	31.5 a (9.21)	22.5 a (5.9)	26.5 a (3.3)	31 a (1.29)	ns
	15-30	49 a (3.96)	35 b (5.68)	30.5 b (4.03)	39.5 ab (0.957)	*
	3-50	48.5 a (2.87)	36 b (3.36)	33.5 b (3.86)	41.5 ab (0.5)	*
Bulk Density (g/cm^3)	0-15	1.91 a (0.245)	2.28 a (0.246)	1.724 a (0.132)	2.35 a (0.292)	ns
	15-30	1.91 b (0.1355)	2.13 b (0.171)	1.77 b (0.103)	3.06 a (0.444)	*
	3-50	2.59 ab (0.502)	3.6 a (0.318)	1.88 ab (0.188)	3.03 b (0.487)	*

a- ANOVA results: Mean values with the same letter within the soil layer do not differ significantly with each other.
** show the significant at the 0.05 level.*

The output of analysis of variance of soil attributes in three depths the four studied stands with interactive effects of stand and depth are presented in Table 3. The stand tree vegetation significantly influenced all soil attributes except for organic C. The depth effects on Clay (%), Bulk Density (g/cm^3), Organic C (%), Total N (%), C:N ratio, Exchangeable Ca (mg/kg), Exchangeable Mg (mg/kg) and Exchangeable K (mg/kg) was statistically significant. The interactive effects of stand and depth was significant only in soil organic C (%).

Results of Duncan test between three soil layers (0-15, 15-30 and 30-50 cm) properties indicated different results for each of stands. As under degraded natural stand (DNS), EC, OC, total N, C:N ratio, available Ca and available Mg were significantly differ between three soil layers. Bulk density, OC, total N and C:N ratio were significantly differ between three soil layers under *A. velutinum* (AV) plantation. Under *A. subcordata* (AS) plantation, OC, total N, C:N ratio and available P were significantly differ between three different soil depths. Also under *C. sempervirens* (CSH), silt and clay percentage, OC, total N, C:N ratio, available Ca and available P were significantly different between three considered soil depths (Fig 1).

Table 2- Soil chemical properties in degraded natural stand and plantations in three soil layers with their standard error (below)

	Depth (cm)	DNS	AV	AS	CSH	ANOVA[a]
pH	0-15	5.77 b (0.125)	7.11 a (0.186)	7.14 a (0.082)	7.2 a (0.206)	**
	15-30	6.03 c (0.211)	7.02 b (0.107)	7.13 ab (0.051)	7.56 a (0.224)	**
	3-50	5.96 c (0.086)	7.12 b (0.149)	7.22 b (0.173)	7.83 a (0.127)	**
EC (ds/m)	0-15	0.549 c (0.444)	12.64 a (1.75)	1.78 c (0.287)	8.81 b (1.39)	**
	15-30	0.42 c (0.018)	10.19 a (1.43)	1.5 c (0.35)	6.67 b (1.64)	**
	3-50	0.463 b (0.021)	9.46 a (1.55)	1.39 b (0.21)	8.87 a (1.07)	**
Organic C (%)	0-15	1.28 ab (0.029)	1.34 a (0.03)	1.33 a (0.003)	1.21 b (0.045)	*
	15-30	0.87 b (0.115)	1.22 a (0.066)	1.17 a (0.053)	1.18 a (0.054)	*
	3-50	1.14 a (0.051)	0.97 a (0.101)	0.93 a (0.135)	0.88 a (0.123)	ns
Total N (%)	0-15	0.2568 b (0.033)	0.4148 a (0.0739)	0.3985 a (0.02)	0.3575 ab (0.023)	*
	15-30	0.0995 b (0.023)	0.248 a (0.055)	0.237 a (0.51)	0.1878 ab (0.013)	*
	3-50	0.1478 a (0.027)	0.1498 a (0.039)	0.1322 a (0.028)	0.116 a (0.022)	ns
C:N	0-15	5.2 a (0.534)	3.52 b (0.571)	3.38 b (0.174)	3.47 b (0.314)	*
	15-30	9.41 a (0.958)	5.43 b (0.722)	5.41 b (0.726)	6.35 b (0.41)	*
	3-50	8.6 a (1.61)	7.21 a (0.975)	7.39 a (0.589)	7.8 a (0.482)	ns
Available P (mg/kg)	0-15	0.085 b (0.029)	0.277 a (0.101)	0.392 a (0.042)	0.282 a (0.045)	*
	15-30	0.082 a (0.059)	0.587 a (0.31)	0.19 a (0.021)	0.205 a (0.035)	ns
	3-50	0.092 a (0.025)	0.512 a (0.362)	0.175 a (0.019)	0.1675 a (0.007)	ns
Available Ca (mg/kg)	0-15	15.28 b (5.92)	47.4 b (9.1)	103.35 a (22.3)	42.47 b (8.342)	**
	15-30	2.25 b (0.868)	25.15 b (10.69)	90.11 a (24.34)	18.81 b (9.004)	**
	3-50	2.93 b (1.3)	22.22 b (7.28)	84.425 a (17.49)	15.23 b (3.31)	**
Available Mg (mg/kg)	0-15	28.97 b (3.44)	42.22 b (2.02)	64.72 a (8.23)	37.97 b (6.04)	**
	15-30	20.22 b (2.36)	31.47 b (3.83)	54.22 a (6.27)	31.97 b (6.95)	**
	3-50	21.22 c (0.5)	32.22 b (3.88)	51.47 a (2.25)	32.47 b (3.37)	**
Available K (mg/kg)	0-15	86 ab (8.94)	101.75 a (19.96)	49.12 b (9.27)	80.62 ab (9.55)	*
	15-30	171.75 ab (36.57)	199.25 a (65.77)	26.37 b (6.23)	191.5 a (65.91)	*
	3-50	165.12 a (46.58)	168.12 a (22.48)	31.1 b (10.41)	252.12 a (63.58)	**

*a- ANOVA results: Mean values with the same letter within the soil layer do not differ significantly with each other. *, ** respectively show the significant at the 0.05 and .001 level.*

Table 3- Analysis of variance of soil attributes in three depths with the interactive effects of stand and depth

	Stand	Depth	Stand × Depth	Error
d.f.	3	2	6	36
pH	5.81**	0.208	0.094	0.095
EC (ds/m)	300.21**	6.66	3.63	4.52
Silt (%)	406.97*	246.08	52.97	93.13
Sand (%)	286.75**	114.08	15.41	37.91
Clay (%)	427.22**	690.08*	35.63	76.77
Bulk Density (g/cm^3)	2.71**	2.23*	0.557	0.369
Organic C (%)	0.02	0.398**	0.074*	0.025
Total N (%)	0.025*	0.21**	0.007	0.006
C:N	14.9**	63.51**	1.97	2.34
Exchangeable P (mg/kg)	0.285*	0.004	0.058	0.083
Exchangeable Ca (mg/kg)	16592.5**	2057.8*	56.4	615.57
Exchangeable Mg (mg/kg)	2342.3**	438.08**	12.55	86.7
Exchangeable K (mg/kg)	46815.6**	27298.7**	7519.11	5843.6

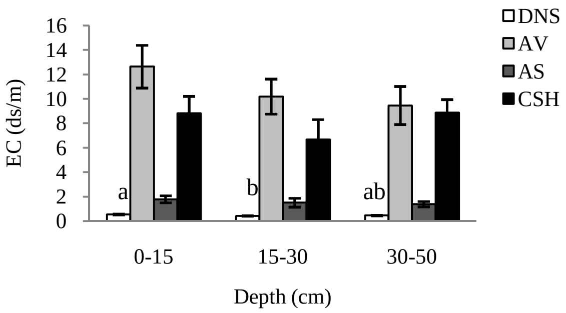
***, ** respectively show the significant at the 0.05 and .001 level.**
d.f. - Degrees of freedom

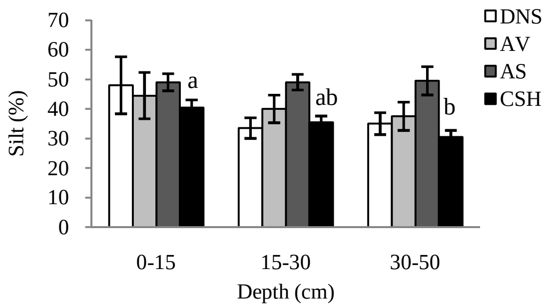
As can be observed in the results that shown in fig 1, in all three plantation stands soil chemical properties contents took the order: 0-15 > 15-30 > 30-50, but under degraded natural stand they followed the order: 0-15 > 15-30 < 30-50. Pattern that observed in soil under the degraded natural stand is probably duo to erosion and leaching which caused by human activities and the degradation because of that.

3.2. Soil C and N stocks

The three plantation stands exhibited no significant differences in soil C and N stocks at the depth of 0-15 and 30-50 cm in comparison to the degraded natural stand while there were significant differences in soil C and N stocks of 15-30 cm soil layer. In this soil layer the CSH stand had the highest amount of these stocks and the DNS had the lowest amount compared to other stands. Also soil C stock was differ significantly between stands across the 0-50 cm depth range but soil N stock was similar between studied stands at this range (Table 4).

Assuming that the C stock of the degraded natural stand is equivalent to the C stock of the plantation stands before the conversion, we concluded that the soil C stock increased under *A. velutinum* (35.47 t/ha) and *C. sempervirens* (31.06 t/ha) and decreased under *A. subcordata* (20.18 t/ha) in 18 years after the conversion. There were no significant differences in soil N stock under studied stands across the 0-50 cm depth range, but all three plantations had increased soil N stock in comparison to the degraded natural stand. What is interesting is that even though *A. subcordata* is one of the nitrogen fixing species, soil under the AS plantation had lower amount of N stock compared to AV and CSH.





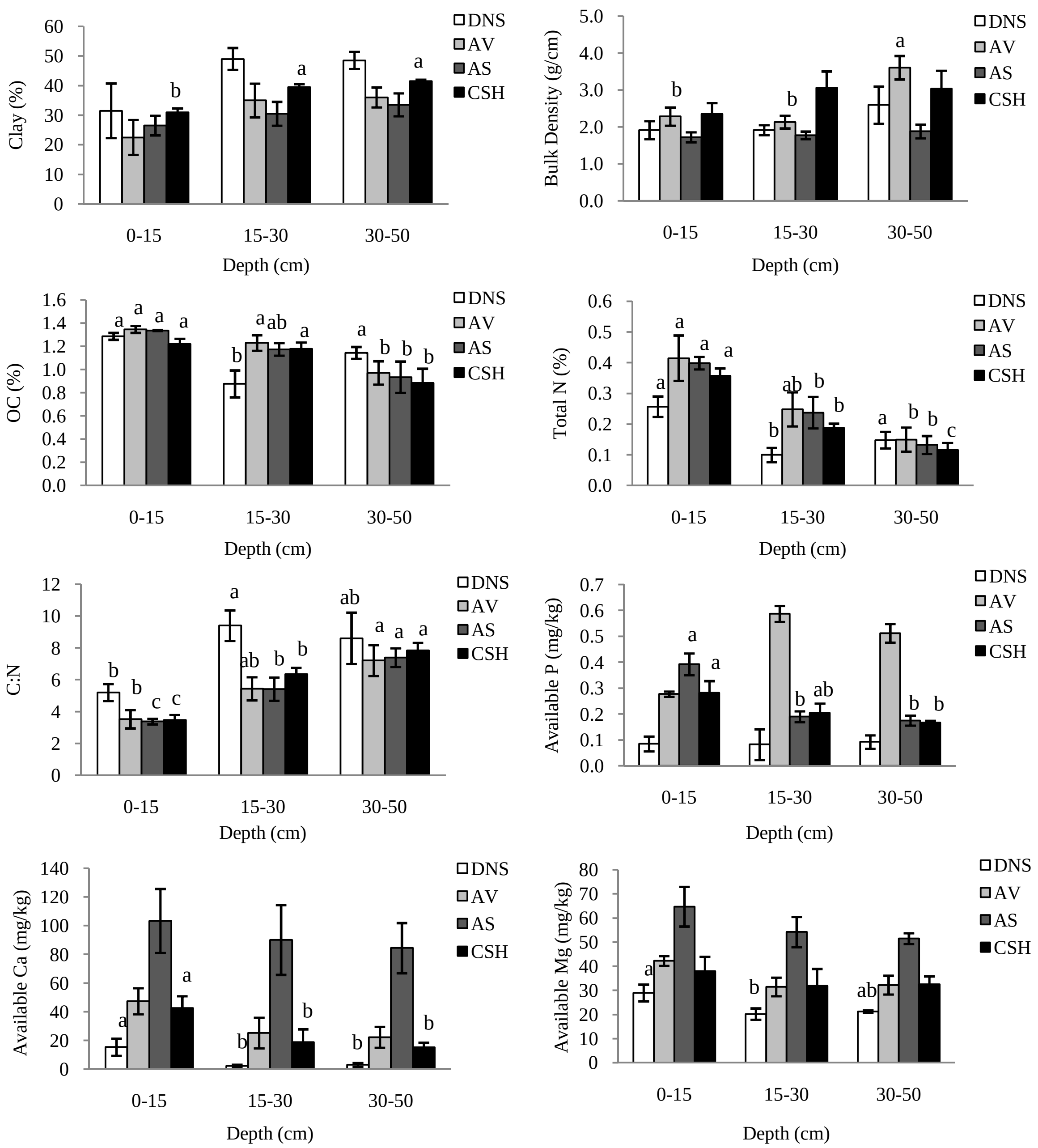


Fig 1- Comparison of soil properties of three different depths under each stand

Table 4- soil C and N stocks under degraded natural stand and three different species plantations

Depth (cm)	DNS	AV	AS	CSH	ANOVA[a]
C stock (t/ha)					
0-15	36.67 ± 3.85	46.18 ± 5.32	34.56 ± 2.66	42.65 ± 4.05	ns
15-30	25.66 b ± 4.95	38.87 ab ± 1.73	31 b ± 0.94	54.73 a ± 9.7	*
30-50	58.45 ± 10.4	71.22 ± 12.01	35.05 ± 6.7	54.47 ± 13.48	ns
0-50	120.8 ab ± 12.89	156.27 a ± 11.7	100.62 b ± 4.5	151.86 a ± 25.8	*
N stock (t/ha)					
0-15	7.31 ± 1.09	14.54 ± 3.6	10.25 ± 0.77	12.9 ± 2.3	ns
15-30	2.9 b ± 0.94	7.6 a ± 1.17	6.18 ab ± 1.18	8.8 a ± 1.86	*
30-50	5.7 ± 0.94	11.11 ± 3.23	4.98 ± 1.33	7.33 ± 2.27	ns
0-50	18.51 ± 3.36	33.26 ± 7.36	21.43 ± 1.8	29.11 ± 6.19	ns

a- ANOVA results: Mean values with the same letter within the soil layer do not differ significantly with each other.
** show the significant at the 0.05 level.*

Out of all possible correlations, 43 correlations were statistically significant, and only four exceeded a correlation coefficient of 0.70 (Table 5). What is important to us is the soil attributes which correlated to organic C and total N. There was strong positive correlation between Organic C and total N. Organic C showed positive correlations with available Ca (mg/kg), percentage of sand and C:N ratio. There were negative correlation between organic C and percentage of clay. Total N was positively correlated with EC, available Ca (mg/kg), available Mg (mg/kg) and percentage of sand. Also there were negative correlations between total N with C:N ratio, available K (mg/kg) and percentage of clay (Table 5).

Table 5- Pearson correlation coefficients (r) among soil attributes across studied stands

	pH	EC (ds/m)	Silt (%)	Sand (%)	Clay (%)	Bulk Density (g/cm^3)	Organic C (%)	Total N (%)	C:N	Available P (mg/kg)	Available Ca (mg/kg)	Available Mg (mg/kg)	Available K (mg/kg)
pH	1												
EC (ds/m)	0.59**	1											
Silt (%)	-0.04	-0.09	1										
Sand (%)	0.36*	0.56**	-0.30*	1									
Clay (%)	-0.20	-0.28*	-0.76**	-0.37**	1								
Bulk Density (g/cm^3)	0.27	0.36**	-0.30*	0.16	0.18	1							
Organic C (%)	-0.03	0.16	0.28	0.29*	-0.46**	-0.17	1						
Total N (%)	0.12	0.31*	0.21	0.55**	-0.57**	-0.15	0.75**	1					
C:N	-0.20	-0.31*	-0.32*	-0.48**	0.64**	0.04	0.69**	-0.9**	1				
Available P (mg/kg)	0.12	0.20	-0.14	0.33*	-0.08	0.03	-0.01	0.13	-0.08	1			
Available Ca (mg/kg)	0.36*	-0.03	0.39**	0.18	-0.50**	-0.38**	0.30*	0.43**	-0.44**	0.02	1		
Available Mg (mg/kg)	0.45**	0.05	0.39**	0.15	-0.48**	-0.36*	0.27	0.43**	-0.45**	0.07	0.92**	1	
Available K (mg/kg)	-0.03	0.18	-0.52**	0.05	0.47**	0.44**	-0.27	-0.35*	0.33*	0.11	-0.61**	-0.58**	1

**, ** respectively show the correlation is significant at the 0.05 and 0.01 level.*

DISCUSSION

4.1. Effects of conversion on soil attributes

As the results of this study showed, conversion of Hyrcanian degraded natural forest to plantations of three native species had considerable influences on soil physical and chemical properties. Results of table 1 indicated that each of three studied species had different effects on soil physical properties. Other studies also reported differences among soil physical properties between different species [18; 28; 51]. In our case, the differences between plantation and the natural stand may be caused by the effects of planting practices and associated disturbance [28]. The observed differences between plantation species may be attributed to their different influences on soil biological community [18]. Lemenih et al., [28] suggested the species dependent difference on soil properties is probably an account of difference in biomass production and nutrient cycle via litter fall and root turnover between the species.

The results of table 2 showed that in comparison to the natural stand, the plantation stands had huge effects on soil chemical attributes. Plantations had increased soil pH compared to the natural stand. Removal of nutrients by intense harvest [36] could have been the main factor controlling the acidity measured under degraded natural stand. It can be also explained by slower litter decomposition of degraded natural stand's species (dominant species was *Quercus castaneifolia*), which leads to the production of organic acids and delays the return of base cations to the soil [18]. Yamashita et al., [56] suggested that this acidification under natural forest could be caused by lower base saturation and related lower amount of exchangeable base cations.
Results showed that plantations had significantly increased soil salinity in comparison to the degraded natural stand. As can be seen in table 2, soil EC was higher in all three plantations and they took order: *A. velutinum* > *C. sempervirens* > *A. subcordata* > degraded natural stand. These differences may be caused by different foliage properties and the amount and quality of litter [18].

In two top soil layers (0-15 and 15-30 cm), soil organic C and total N were significantly higher under plantations compared to the natural stand. It is obvious, that the upper and lower soil layers are affected by different factors to various extents. Differences in aboveground litter quality as well as deposition inputs, mostly lead to differences in chemical properties of upper soil layers. But if the differences in soil chemistry were caused by differences in root uptake and turnover, they will be as sensible in the lower layers as in the upper layers, assuming that the root distribution and activity as well as weathering and leaching were relatively similar between the layers [18].

Results from other studies in tropical and temperate regions show that soil C and N changes following afforestation or reforestation are quite variable, with soil C and N levels either increasing or decreasing. For instance, in a study of native forest and mature *P. radiata* plantation, Turner and Lambert [52] found that soil organic C under *Pinus* was lower than that under adjacent native forest. In another study under *P. radiata* and *E. grandis*, Turner and Lambert [53] observed an ongoing decline in soil organic carbon for 12 years; thereafter, soil C stabilized and increased nearly age 20 years. Therefore, we conclude that organic C and total N in forest soils are markedly variable depending on tree species and age, soil type, climate, management practices and initial soil status.

In the results *A. velutinum* and *A. subcordata* plantation had more desirable effects on soil organic C and total N than the *C. sempervirens* plantation which this might be due to the lower tree survival and density that observed in the *C. sempervirens* plantation stand.

Soil C:N ratio is an index of N mineralization [5, 50, 36]. The mineralization rate is low at higher C:N ratios, and as a consequence soil nutrient levels decrease [36]. Large C:N ratios under degraded natural forest likely resulted from low mineralization rates and consequently their levels of total N and available nutrients were low. As can be seen in table 2, in three considered soil depths, all studied soil nutrients were significantly differ between the stands except for available P. Soil available P showed significant differences just in top soil layer (0-15 cm) which may be caused by differences in litter quality and deposition inputs. Results showed that all three plantation stands had great effects on soil available nutrients. Most of nutrients significantly increased after conversion of degraded natural forest to the plantations but under the *A. subcordata* plantation soil available K was lower than the degraded natural forest. On the other hand, *A. subcordata* plantation had higher concentrations of available P, available Ca and available Mg than other studied stands. Our suggestion is that P is one of the main elements which used in biomass productivity of *A. subcordata* trees, and due to the utilization of this element, under *A. subcordata* plantation concentration of available P is lower than natural forest but further study is necessary at this topic.

Three factors may explain the low levels of nutrients in soils of degraded natural forest. First, clay particles lose their capacity to absorb base cations when soil acidity increases. As a consequence, higher amounts of cations are present in soil solution and are free to leach into deeper soil profiles [29, 19, 25, 36]. Second, under low pH, the organic matter is difficult to mineralize and therefore, soil nutrient levels are not enhanced [36]. Third, degradation caused by human activity has led to a reduction in tree density and canopy cover and so it led to increase nutrients leaching. Chen and Li [12] also corroborate human activities such as trees cutting, could affect soil nutrient decomposition or loss. They said after human activities (such as harvesting and logging), soil temperature and precipitation on the forest floor will be increased due to removal of canopies, which increases litter decomposition. Therefore, rates of litter decomposition will increase, but many nutrients will be lost with increasing runoff.

Nutrient-rich needles, branches, twigs and coarse litter fractions are important nutrient sources [12] after the conversion these sources increased by higher tree densities in plantations. On the other hand with increasing the canopy covers, nutrient leaching reduced under the plantations. We believe these are the most important factors that increased soil nutrients under the plantation stands in comparison to the degraded natural forest.

As can be observed in fig 1, under plantation stands changes in soil chemical properties among soil layers followed the normal process and decreased with increasing in soil depths. But under the natural stand soil chemical properties (such as EC, organic C, total N and available nutrients) were higher in lower depth (30-50 cm) than the middle depth (15-30 cm) which this probably caused by leaching of the elements due to the degradation.

In most researches that have studied conversion of natural forests to plantations, the conversion had negative influences on soil organic C and nutrients [17, 12, 28] but in our study due to the degradation that occurred in natural stand, the plantation stands had positive influences on soil organic C and nutrients. Soil attributes under plantations depends on the prior plantation establishment site soil fertility. When established on degraded lands, the effects are assumed beneficial, whereas when grown on newly cleared forest sites the effects are reported to be adverse [28, 58]. In this study the natural forest was degraded by human activities. We assumed that the soil attributes of the degraded natural forest are equivalent to the soil attributes of the plantation stands before the conversion. Therefore, according to results of this research, within 18 years since establishment of the plantations, they showed positive influences on most soil properties.

4.2. Soil C and N stocks

Plants play an important role in regulating the biogeochemistry of ecosystems by fixing carbon and nitrogen and preventing the loss of nutrients [12]. Soil organic carbon is very important in terrestrial ecosystems since it plays a crucial role in the formation and maintenance of soil structure, fertility, nutrient and water availability [13, 49, 31]. On the other hand, soil N increase is also very important in degraded land rehabilitation projects [31]. In addition, soil C and N stocks can be an appropriate criterion to assay the success of these rehabilitation projects. In results, only in 15-30 cm soil layer C and N stocks were significantly different between the degraded natural stand and plantations. Across the 0-50 cm depth range, only soil C stock was significantly differ between studied stands and the differences were not significant in soil N

stock in this depth range. In comparison to the degraded natural stand, *A. velutinum* and *C. sempervirens* increased and *A. subcordata* decreased soil C stocks. After plantation establishment, there are reduced inputs of carbon into the soil from prior land-use, together with accelerated decomposition of soil organic matter as a result of disturbance, and this leads to a net loss of soil organic carbon [53, 42]. Arevalo et al., [4] suggested that soil C loss in the early stages of plantation development may be due to lesser organic C inputs than organic C outputs. In some systems this loss of soil organic carbon is not balanced until 5-10 years after establishment and on some sites, a reduction in soil organic carbon may remain until the end of the rotation. The patterns of accumulation and loss of carbon vary according to location, soil type, tree species and plantation management system [53]. So we think that under *A. velutinum* and *C. sempervirens* plantations, after 18 years of establishment, soil organic carbon balanced and then even increased in compared to the degraded natural stand. But under *A. subcordata* probably it will be taking longer time for soil organic carbon to balance. Early soil C loss under young plantations followed by increased soil C stock with plantation age was observed by Arevalo et al., [4] so we expect an increase in soil C stock with increasing of the plantations age.
Many studies reported that after native forests were changed into plantations the soil carbon stock declined [2, 17, 12, 26, 54]. They suggested that species composition, age of plantation, and precipitation have significant effects on soil carbon stock in plantations. While a number of studies did not observe any discernible patterns in soil C stock related to or influenced by land use or forest age [22]. Here due to the degradation of natural forest, *A. velutinum* and *C. sempervirens* plantation stands had improved soil C stock. Islam and Weil [23] were similarly observed an increase in soil C and N stocks after conversion of a degraded natural forest to *Acacia* reforestation. They suggested that degradation of soil quality may have resulted from increased disruption of macroaggregates, reductions in microbial biomass, and loss of labile organic matter due to fire, deforestation, tillage and accelerated erosion. However, the rate of soil C stock increase will inevitably slow down as the soil C concentration increases with time [48, 47, 31]. According to Silver et al., [47], the annual rate of soil C incorporation will be reduced to 0.20 (Mg/ ha/ year) in the next 80 years, after experiencing a higher incorporation rate (1.3 Mg/ ha/ year) over the first 20 years. At this point, it is important to emphasize the role of plantation soils as C sink during the first 20-50 years.

Many studies have found that nitrogen-fixing species can significantly increase soil N levels [40, 12, 31] while others found no correlation between the presence of nitrogen-fixing species and total N accumulation in the surface soil [14]. It was expected that *A. subcordata* as a nitrogen-fixing species may have a greater soil N stock than other studied species but it had lower one.

There was strong positive correlation between organic C and total N (Table 5). Many other studies have reported the same relation between soil organic carbon and nitrogen [35, 42, 55, 38] while others found no correlation between organic C and total N of soil [23]. Varamesh et al., [55] in their studies on *Robinia pseudoacacia* and *Cupressus arizonica* in an urban forest of Tehran observed significant correlations between soil organic C and gravel, clay, silt, sand and pH. They also found significant correlations between soil total N and clay, sand, organic matter and C:N ratio. They concluded that volume and quality of carbon storage are close related to action and reaction between climate, soil, tree species, management and chemical composition of litter. Richards et al., [42] proposed that managing the relations between organic C and other soil properties may be a crucial prerequisite for maintaining and increasing levels of soil organic carbon under plantations.

CONCLUSION

Our results showed that conversion of degraded natural forest to plantations improved soil nutrients and stocks of C and N in soil. All three studied species had increased soil nutrients compared to the degraded natural forest except for soil available K which decreased under *A. subcordata* plantation. We expect increasing the soil nutrient improvement with increasing the age of plantation stands. Our study demonstrates that conversion of degraded natural forest to *A. velutinum* and *C. sempervirens* plantations increased soil C and N stocks. But conversion to *A. subcordata* plantation decreased soil C stock and increased soil N stock although differences were not significant. These results concluded that tree species and age of plantation stands can be effective factors that influence the soil C and N stocks. In addition, it is important to consider that such plantations may have an important potential to transform degraded forest stands into rehabilitated areas that function as a C sink, helping to mitigate the negative impacts of the greenhouse effect. Therefore, establishment of plantation in degraded Hyrcanian forests will restore soil nutrients and contribute to climate change mitigation by increasing carbon stock in soils and it will play a fundamental role in ecosystem productivity and environmental protection.

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REFERENCES

[1] L.E. Allison; Organic carbon In: Black, C.A. (Ed.), Methods of Soil Analysis. American Society of Agronomy, Part 2, Madison,WI, **1975**, 1367-1378.
[2] I. Amponsah, W. Meyer, *Communications in Soil Science and Plant Analysis*, **2000**, 31, 355-373.
[3] Anonymous, Oshtorvash Forest Management Planning, Organization of Forest and Rangelands and Watershed Management. Islamic Republic of Iran, **1994**, 370 p (In Persian).
[4] C.B.M. Arevalo, J.S. Bhatti, S.X. Chang, D. Sidders, *Forest Ecology and Management*, **2009**, 257, 8, 1776-1785.
[5] G. Bengtsson, P. Bengtson, K.F. Mansson, *Soil Biology and Biochemistry*, **2003,** 35, 143-154.
[6] G. R. Blake, K.H. Hartge, *Soil Science Society of America*, **1986,** 9, 1, 363-376.
[7] G.J. Bouyoucos, *Agronomy Journal*, **1962,** 56, 464-465.
[8] C.A. Bower, R.F. Reitemeier, M. Fireman, *Soil Science*, **1952**. 73, 4, 251-261.
[9] J.M. Bremmer, *Journal of Agricultural Science*, **1960**, 55, 13, 11-33.
[10] M.G.L. Cannell, *New Forests*, **1999**, 17, 239-262.
[11] R.L. Chazdon, *Science*, **2008**, 320, 1458-1460.
[12] X. Chen, B.L. Li, *Forest Ecology and Management*, **2003**, 186,197-206.
[13] E.T. Craswell, R.D.B. Lefroy, *Nutrient Cycling in Agroecosystems*, **2001**, 61, 7-18.
[14] J.R. Cromack, R.E. Miller, O.T. Helgerson, R.B. Smith, H.W. Anderson, *Soil Science Society of America Journal*, **1999**, 63, 232-239.
[15] J. Evans, *New Forests*, **1999**, 17, 25-36.
[16] M.R. Guariguata, R. Ostertag, *Forest Ecology and Management*, **2001**, 148, 185-206.
[17] L.B. Guo, R.M. Gifford, *Global Change Biology*, **2002**, 8, 345-360.
[18] A. Hagen-Thorn, I. Callesen, K. Armolaitis, B. Nihlgrad, *Forest Ecology and Management*, **2004**, 195, 373-384.

[19] A.E. Hartemink, Soil fertility decline in the tropics with case studies on plantations, CABI, London, UK, **2003**, 360 p.
[20] R. Hernandez, P. Koohafkan, J. Antoine, Assessing carbon stocks and modeling win-win scenarios of carbon sequestration through land-use changes, Food and Agriculture Organization of the United Nations, Rome, **2004**, 166 p.
[21] C.D. Homer, P.F. Pratt, Methods of analysis for soils, plants and waters, University of California, Agricultural Sciences Publications, Berkeley,**1961**, 309 p.
[22] R.F. Hugues, J.B. Kauffman, V.J. Jaramillo, *Ecology*, **1999**, 80, 1892-1905.
[23] K.R. Islam, R.R. Weil, Agriculture, *Ecosystems and Environment*, **2000**, 79, 9-16.
[24] P. Jagger, J. Pender, *Forest Policy and Economics*, **2003**, 5, 83-95.
[25] E.G. Jobbagy, R.B. Jackson, *Biogeochem*, **2003**, 64, 205-229.
[26] S. Kasel, L.T. Bennett, *Geoderma*, **2007**, 137, 401-413.
[27] M. Khosroshahi, S. Ghavvami, Warning, the conservation of nature, Poone Publishing, Tehran, **2006**, 155 pp.
[28] M. Lemenih, M. Olsson, E. Karltun, *Forest Ecology and Management*, **2004**, 195, 57-67.
[29] J. Lilienfein, W. Wilcke, M.A. Ayarza, L. Vilela, S.C. Lima, W. Zech, *Forest Ecology and Management*, **2000**, 128, 145-157.
[30] C.J. Losi, T.G. Siccama, R. Condit, J.E. Morales, *Forest Ecology and Management*, **2003**, 184, 355-368.
[31] M.O. Macedo, A.S. Resende, P.C. Garcia, R.M. Boddey, C.P. Jantalia, S. Urquiaga, E.F.C Campello, A.A. Franco, *Forest Ecology and Management*, **2008**, 255, 1516-1524.
[32] T. Maranona, R. Ajbiloua, F. Ojedab, J. Arroyob, *Forest Ecology and Management*, **1999**, 115, 147-156.
[33] K.G. Mc Dicken, A Guide to Monitoring Carbon Storage in Forestry and Agro forestry Projects, Winrock International Institute for Agricultural Development, Forest Carbon Monitoring Program, **1997**, 91 p.
[34] A. Mishra, S.D. Sharma, G.H. Khan, Forest Ecology and Management, **2003**, 184, 115-124.
[35] J.C. Neff, A.R. Townsend, G. Gleixner, S.J. Lehman, J. Turnbull, W.D. Bowman, *Nature*, **2002**, 419, 915-917.
[36] D. Nsabimana, L. Klemedtson, B.A. Kaplin, G. Wallin, *African Journal of Environmental Science and Technology*, **2008**, 2, 6, 142-149.
[37] K.I. Paul, P.J. Polglase, J.G. Nyakuengama, P.K. Khanna, *Forest Ecology and Management*, **2002**, 168, 241-257.
[38] M. Paul, C.P. Catterall, P.C. Pollard, J. Kanowski, *Forest Ecology and Management*, **2010**, 259, 2083-2092.
[39] M. Poorzady, F. Bakhtiari, *iForest - Biogeosciences and Forestry*, **2009**, 2, 198-206.
[40] S. Resh, D. Binkley, J.A. Parrotta, *Ecosystems*, **2002**, 5, 217-231.
[41] J.M. Rey Benayas, A. Martins, J.M. Nicolau, J.J. Schulz, CAB Reviews: Perspectives in Agriculture**,** Veterinary Science**,** Nutrition and Natural Resources**, 2007,** 2, 14p.
[42] A.E. Richards, R.C. Dalal, S. Schmidt, *Soil Biology & Biochemistry*, **2007**, 39, 2078-2090.
[43] K. Sagheb-Talebi, In: XXI IUFRO Word Congress-Forests and Society: The Role of research, 7–12 August, Kuala Lumpur, Malaysia, **2000**, 67-75.
[44] K. Sagheb-Talebi, T. Sajedi, F. Yazdian, Forests of Iran, Research Institute of Forests and Rangelands Publishing, Iran, **2004**, 339p.
[45] K. Sagheb-Talebi, F. Yazdiyan, A look to the forests of Iran, Iranian Research Institute of Forest and Rangelands, Iran, **2005**, 285p.
[46] A. Salehi, G. Zahedi-Amiri, D.F.R.P. Burslem, M.D. Swaine, *Asian journal of plant sciences*, **2007**, 6, 3, 455-462.
[47] W.L. Silver, R. Ostertag, A.E. Lugo, *Restoration Ecology*, **2000**, 8, 394-407.

[48] J. Six, R.T. Conant, E.A. Paul, K. Paustian, *Plant and Soil*, **2002a**, 241, 155-176.
[49] J. Six, C. Feller, K. Denef, S.M. Ogle, J.C. Moraes-Sa, A. Albrecht, *Agronomie*, **2002b**, 22, 755-775.
[50] G. Springob, H. Kirchmann, *Soil Biology and Biochemistry*, **2003**, 35, 629-632.
[51] T.D. Turk, M.G. Schmidt, N.J. Roberts, *Forest Ecology and Management*, **2008**, 255, 1874-1882.
[52] J. Turner, M. Lambert , *Forest Ecology and Management*, **2000**, 133, 231-247.
[53] J. Turner, M.J Lambert, D.W. Johnson, *Forest Ecology and Management*, **2005**, 220, 259-269.
[54] P. Vallet, C. Meredieu, I. Seynave, T. Belouard, J. Dhote, *Forest Ecology and Management*, **2009**, 257, 1314-1323.
[55] S. Varamesh, S.M. Hosseini, N. Abdi, M. Akbarinia, *Forest Science*, **2009**, 3, 75-90.
[56] N. Yamashita, S. Ohta, A. Hardjono, *Forest Ecology and Management*, **2008**, 254, 362-370.
[57] R. Zdenko, Handbook of plant growth: pH as the master variable, Marcel Dekker Incorporated, New York, NY, USA, **2002**, 323 p.
[58] H. Zerfu, Ph.D. thesis, Institute of Forest Ecology, Vienna University of Agricultural Sciences, Vienna, **2002**.