

Biomass and carbon sequestration of native forests in the northwest of Iran

Ebrahim Fataei

¹ Department of Environmental science, Ardabil Branch, Islamic Azad University
Ardabil, Iran , Email: ebfataei@gmail.com

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Abstract: The estimation of carbon storage and accumulation in forest ecosystems is necessary to assess the role of these resources in the global carbon budget. Therefore, we considered the potential and distribution of organic carbon in the natural pure and mixed beech, oak and maple forests of Fandogloo region of Ardabil province in Iran. In each stand, 6-nested plots were used in the square shape. four profiles were used in each plot and the soil samples were taken from three depths. The highest amount of soil organic carbon sequestration was found in the mixed stand of oak-maple (26.35 Mg.ha⁻¹). The same trend was seen in the amount of total nitrogen (TN) in the soil. The highest amount of carbon sequestration was observed in the forest floor litter in the mixed stand of maple - beech (4.11 Mg.ha⁻¹). The high amount of carbon sequestration in the mixed stand of oak - maple may be due to the lower amount of clay in the soil of this stand. It is likely that the soil fertility is low in the maple-beech stand so that the activities of microorganisms are less than other stands so that due to no degradation, the accumulation of litter has occurred. Totally, the pure beech stand showed the highest amount of total carbon sequestration in the entire pure stand (61.93 Mg.ha⁻¹). The high above- and belowground biomass in the beech stand was the effective factor to increase the total carbon sequestration compared to other stands.

Keywords: Above and belowground carbon; beech; maple; oak; total nitrogen

1. Introduction

The entrance of carbon to the terrestrial carbon cycle is photosynthesis in which CO₂ of atmosphere is absorbed and turned into the organic matters (Haster and Harrison, 2010). The forest ecosystems of the world are the main sink of carbon in the terrestrial ecosystems (Yue et al., 2018). The carbon in biomass of forest ecosystem consists of woods, branches, leaves and roots and dead plant parts, such as litter, woody debris and soil (Lal, 2005). Due to the high potential for long and immediate storage, the biomass of forests and their soil have drawn attentions (Houghton, 2005).

The carbon accumulation in the various ecosystems, such as forests has become an important issue all around the world and

the estimation of carbon storage has been considered in the biomass and soil through several studies (Raha ,et al., 2020).

The estimation of stock and accumulation of carbon in the forest ecosystems are essential to assess the role of these ecosystems in the global carbon budget (Uri et al., 2012). The important subject is the contribution of the components of a forest ecosystem in the sequestration and storage of carbon. The consideration of forest stands in the complex form of trees, understory, soil and litter are needed to obtain better understanding of the carbon sequestration potential of forest ecosystems (Uri et al., 2012).

Most biomass and carbon in forest ecosystems are usually found in tree



biomass components, such as trunks, branches and leaves, while understory biomass and land coverage along with standing dead trees and debris play an integral role in this regard (Kothandaraman et al., 2020). Therefore, not paying attention to the secondary biomass and carbon reservoir may lead to significant neglect of the total carbon storage. Apart from the aboveground coverage, tree roots and mineral soil is the main sink of large amount of carbon (Oliver et al., 2004). The calculations of root biomass and estimation of carbon stock in roots may be crucial (Peichl and Arain, 2006). Meanwhile the tree species can have remarkable impact on the carbon sequestration in an ecosystem. The tree species have a wide range of mechanisms affecting the soil properties. Xiao-Wen, et al (2009) concluded that forests with different types of trees can cause significant changes in the carbon and nitrogen of soil. The carbon distribution in the various components, including above- and belowground biomass and litter are also different. Peichl and Arain (2006) noted the role of the carbon storage in different parts of a pine forest ecosystem. Understanding of the nitrogen cycle in an ecosystem is essential to realize the source or long-term sink of carbon (De Vries et al., 2006).

Beech, oak and maple are important species in the natural forests of Iran. There are just few sources of carbon sequestration in the existing natural forests of Iran. Most studies focused on planting of fast-growing and coniferous trees on the

carbon sequestration. Therefore, in this study the relationship between the SOC and TN also were examined.

The main purpose of this study was to evaluate carbon storage in natural ecosystems of pure beech and mixed beech -oak and oak - maple stands. Consequently, the main goal of this study is to quantify the above- and belowground biomass, the litter of forest floor, the carbon sequestration and its distribution in the different components of stands considered. It is assumed that under the relatively homogeneous biophysical conditions, different broad-leaved species in the form of natural pure and mixed ecosystems have a wide range of effects on the carbon sequestration in the soil components, the above- and belowground biomass and the litter of forest floor.

2. Materials and methods

2.1. Study Area

The study area is located in the northwest of Iran and in the northeast of Ardabil province. (Fig1). According to the meteorological station of the region, the average annual rainfall was 379 mm and the average annual temperature was 8.8 ° C. The height of the studied forest area was in the range of 1350 to 1500 meters above sea level. The study area was 50 hectares. This area includes the pure beech stand and also the mixed oak - maple and maple – beech stands. The soil texture of the study area is loam and clay loam.

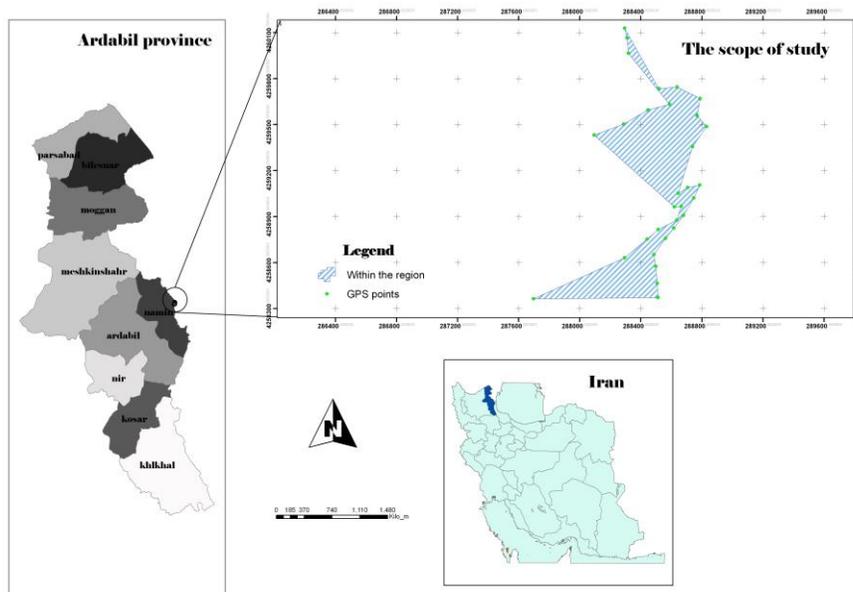


Fig 1: . Location of study area (Fandogloo Forest in Ardebil Province, Iran)

2.2. Sampling Method

First of all, 50-hectare section of total region was selected for this study. In order to reduce the border effects, the rows around the stands were not considered during sampling (Fataei et al., 2018). Sampling was conducted in autumn through a systematic random method. In each stand, 6-nested plots (20×20 m for the inventory of quantitative properties of trees, 10×10 m for the soil sampling (Lemma, et al., 2006) and 0.5×0.5 m for the litter sampling) were extracted in the square shape. In 20×20 m sampled plots, the quantitative characteristics of all the trees inside were measured, including diameter at breast height (DBH), total height (H) and trunk height (HC), and two perpendicular diameters of the canopy (W & L). The litter sampling based on the direct sampling was taken in the plot size of 0.5×0.5 m at the four corners of the 20×20 m- plots (1997 Mc Dicken). In each sampling station, 100m^2 (10×10 m) plots were used for the soil sampling (Lemma et

al., 2006). Four one-meter profiles were dug in each plot and the soil samples were extracted from the deep levels of 0-15, 15-30 and 50-30 cm using a core sampler. In each plot within each station, samples were taken from 4 points in the form of a composite sample used for the soil analyses. The bulk density of soil was measured to calculate the carbon storage of soil. For this subject, the samples were extracted from the pits dug in each plot of different levels (0-50 cm) using a cylinder ($d=40$ mm and volume 50 cm^3) to prevent from compaction and maintain the soil structure. Three samples were taken from different depths (Uri et al., 2012). All the soil samples were derided (25° C) and sieved by mesh of 2mm and coarse material livings, such as roots and gravels were separated, while collapsing organic matters like dead plant roots were defragmenter and added to materials sieved (Lemma, et al., 2006).

2.3. Soil analysis

2.3.1. General characterization

The bulk density was gained by dividing the oven dry mass of the <2 mm fraction by the volume of the core at 105 °C. The volumes of roots and gravels were taken into account, but made up <4% in most of the samples (Lemma et al., 2006). The pH was measured using a pH meter of Orion Analyzer Model 901 a soil: water ratio of 1:2.5. The EC was measured by Electrical conductivity meter a soil: water ratio of 1:2.5. The soil texture was determined by Bouyoucos hydrometer method (Bauder, 1986).

The base saturation was measured using saturate mud and TN using Kjeldahl. The amounts of phosphorus, organic matter and calcium were determined using Olsen method (1954), the Walkley-Black (Sahrawat, 1982), and atomic absorption spectrophotometry model GBC 932A / A, respectively.

2.3.2. Calculation of SOC and TN

The total organic carbon and nitrogen stocks (Mg ha^{-1}) of each depth (0-15, 15-30 and 30-50 cm) of soil was calculated by the equations below:

$$\text{SOC } (\text{Mg ha}^{-1}) = \text{SOC } (\text{g kg}^{-1}) \cdot z \cdot \rho_b \cdot 10 \quad (\text{Eq. 1}) \quad (\text{Lemma, et al, 2000})$$

$$\text{Total N } (\text{Mg ha}^{-1}) = \text{N } (\text{g kg}^{-1}) \cdot z \cdot \rho_b \cdot 10 \quad (\text{Eq. 2}) \quad (\text{Lemma and Olsson, 2006})$$

Where, z is soil layer thickness (m), and ρ_b is dry bulk density (Mg m^{-3}).

2.3.3. Calculation of biomass

To calculate tree biomass and to compute trunk, canopy and root volume, the following steps were done according to prescription (Hernandez et al. 2004):

In the beginning, the base area of the tree was calculated using equation (1) and then

the volume of the tree was obtained using equation (2). Finally, trunk biomass (kg) was calculated according to equation (3).

$$Ab = \pi r^2 \quad (\text{Eq. 3})$$

Where, $\pi = 3.1415927$; and r is the radius of the tree at breast height (0.5 DBH).

$$V = Ab \times H \times Kc \quad (\text{Eq. 4})$$

Where, Ab is the basal area; H is the height; and Kc is a site-dependent constant in standard cubing Practice used in forest Inventory (0.5463).

$$\text{Biomass} = V \times WD \times 1000 \quad (\text{Eq. 5})$$

Where, V = volume of the trunk and WD = wood density.

Since the full sampling of tree roots is time demanding and expensive and also in order to avoid destructive sampling methods, the root biomass was calculated using equation number 4 (Hernandez et al. 2004)

$$\text{BGB} = \text{VolumeAGB} \times 0.2 \quad (\text{Eq. 6})$$

Where, BGB = Belowground biomass and AGB = Aboveground biomass

The volume of tree canopies was computed by Equation (7).

$$V(m^3) = \frac{\pi \times Db^2}{12} \quad (\text{Eq. 7})$$

Where, $\pi = 3.141592$; Db = diameter of the crown (to compute Db , the average of the field measurements L and W is taken and used as the diameter of the crown: $Db = (L + W)/2$); Hc = height from the ground to the base of the crown.

2.3.4. Carbon sequestration of biomass and litter:

The carbon sequestration of biomass was calculated based on equation below (Mc Dicken, 1997).

$$C = \text{Biomass}_{(\text{total})} \times 0.55 \quad (\text{Eq. 8})$$

To calculate the carbon storage of litter, four samples resulting from samples collected from sampling of 0.5*0.5 in the four corners of the 20*20 plot were mixed together and then 20- grams of samples were isolated and milled (1997 Mc Dicken). The samples were dried in the oven (at 70 °C for 24 h) and the organic carbon in the samples was estimated using electrical furnace combustion method. By determining the weight of ash and having initial weight and ratio of organic carbon to the organic matter, the organic carbon content of litter was calculated by the following equation(6) (Mc Dicken, 1997; Birdsey et al, 2000; Losi et al, 2003).

$$OC = 1/2 \times OM \quad (\text{Eq. 9})$$

2-3-5- Statistics:

In the first step, the normality of the data was determined using the Kolmogorov-Smirnov test. Analysis of variance (ANOVA) data was performed using SPSS 19 software. Significant interactions between stand-depth were performed using two-way analysis of variance (two-way ANOVA and stand effects on the quantitative traits and the carbon sequestration of the various components were performed using one-way ANOVA. When differences were significant, the differences between the means were assessed using the Duncan test at the 5% level. Pearson correlation was used to examine the relationship between data.

3. Results

3.1. Physico-chemical properties of the soil:

Three stands considered showed significant differences (Table 1). The results depicted the highest acidity (pH) of soil in the mixed maple-beech stand and in the lower depth (30-50 cm) which showed no significant difference with two upper depths (0-15 and 15-30 cm). Pure beech stand at the three depths showed no significant differences in various pH values. But mixed oak-maple stand at the first depth was significantly different with the two lower depths. The soil bulk density increased with the increasing of depth in the both beech and oak-maple stands. Similar trend was not observed in the maple-beech stand between the first and second depths, and the numerical differences were not statistically significant in the two depths. The highest soil EC was in the first depth of oak-maple stand. There was no significant difference in the other stands. In general, the highest percentage of sand was viewed in the first depth of the pure beech stand. However, it showed no significant differences with the other depths. Among all stands, only oak-maple stand showed significant difference in the percentage of sand in the first depth with two lower depths. The clay percentage was not significantly different in the stands considered. In the first depth, the percentage of silt in the oak – maple stand had significant difference with two other depths. The other stands presented no significant differences in the percentage of silt. The results depicted that calcium and phosphorus were not significantly different in three stands and mentioned depths.

Table 1. the effect of stand–depth interactions of some soil properties

Soil properties	Depth (cm)	Stand			ANOVA F-Value (stand×depth)		
		beech	maple-beech	oak-maple			
PH _{H2o}	0-15	5.59±0.07 ^d	5.87±0.03 ^{abc}	5.96±0.02 ^{ab}	3.188*		
	15-30	5.68±0.1 ^{bcd}	5.86±0.01 ^{abc}	5.49±0.02 ^d			
	30-50	5.47±0.09 ^d	6.01±0.02 ^a	5.60±0.01 ^{cd}			
Bulk density (gr/ cm ⁻³)	0-15	1.40±0.02 ^b	1.50±0.23 ^{ab}	1.42±0.01 ^b		2.977*	
	15-30	1.49±0.03 ^{ab}	1.40±0.30 ^b	1.48±0.03 ^{ab}			
	30-50	1.55±0.03 ^a	1.46±0.33 ^{ab}	1.51±0.03 ^{ab}			
EC (dS m ⁻¹)	0-15	0.02±0.01 ^b	0.02±0.01 ^b	0.05±0.01 ^a			4.04**
	15-30	0.02±0.01 ^b	0.02±0.01 ^b	0.02±0.01 ^b			
	30-50	0.03±0.01 ^b	0.01±0.01 ^b	0.02±0.01 ^b			
Base saturation (%)	0-15	19.13±0.58	17.67±0.43	17.33±0.43	0.469 ^{ns}		
	15-30	21.75±1.59	20.67±0.7	20.33±1.1			
	30-50	23.13±1.48	24.00±0.43	19.67±3.2			
Sand (%)	0-15	46.13±3.06 ^a	35.33±0.31 ^{bcd}	25.33±2.34 ^d		3.90*	
	15-30	44.25±2.83 ^{ab}	27.33±0.33 ^d	42.00±2.76 ^{ab}			
	30-50	41.88±2.39 ^{ab}	28.33±0.33 ^{cd}	38.00±0.33 ^{abc}			
Clay (%)	0-15	26.13±1.37	28.67±0.33	24.67±0.31			1.23 ^{ns}
	15-30	29.00±1.15	31.33±0.67	26.33±0.33			
	30-50	29.25±1.77	31.33±0.31	21.33±0.29			
Silt (%)	0-15	27.75±2.63 ^c	36.00±0.24 ^{bc}	50.00±0.31 ^a	3.41*		
	15-30	26.75±2.48 ^c	41.33±0.33 ^{ab}	31.67±0.27 ^{bc}			
	30-50	28.88±2.73 ^c	40.33±0.29 ^b	40.67±0.29 ^b			
available P (ppm)	0-15	17.13±0.85	15.00±0.23	15.00±1.23		0.912 ^{ns}	
	15-30	20.38±1.21	20.67±0.31	21.67±1.1			
	30-50	18.38±1.00	15.67±0.25	17.33±0.56			
Ca+2 (%)	0-15	1.56±0.2	2.47±0.01	2.60±0.01			1.4 ^{ns}
	15-30	1.70±0.24	2.24±0.01	1.77±0.03			
	30-50	1.60±0.20	2.74±0.02	2.16±0.01			

* $p < 0.05$, ** $p < 0.01$ and ^{ns} = not significant

3.2. SOC sequestration and TN

The main effects of stands on the sequestration of SOC and TN are presented in Fig 2. There was the significant difference in the SOC sequestration and TN of stands. The highest SOC sequestration was observed in the mixed stand of Quercus - Acer (26.35 Mg / ha) (Fig 2a) which showed significant differences in Fagus stand (21.47 Mg.ha⁻¹),

but it showed significant difference in Acer - Fagus stand (18.04 Mg.ha⁻¹). The highest amount of TN was observed in pure Fagus stand (1.91 Mg.ha⁻¹). It had no significant difference with mixed Quercus - Acer (1.79Mg.ha⁻¹), but they had statistically significant difference with mixed Acer - Fagus (1.40 Mg.ha⁻¹) (Fig 2b).

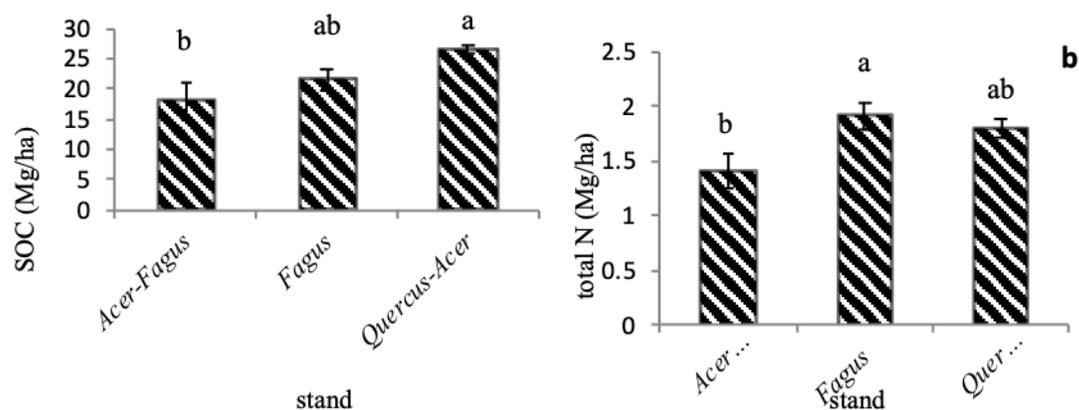


Fig 2. Mean (\pm S.E.) of SOC and TN (Mg ha^{-1}) sequestration within 0-50 cm depth under different stands.

The changes in SOC and TN were found in the three depths of 0-15, 15-30 and 30-50cm. They showed significant difference in the amount of the SOC and TN in the three depths (Fig. 3). Accordingly, the highest SOC was found in depth of 30-50 cm ($25.15 \text{ Mg}\cdot\text{ha}^{-1}$), and it had no significant difference with the first depth ($20.98 \text{ Mg}\cdot\text{ha}^{-1}$). The lowest SOC was observed in the middle depth (15-30 cm)

($19.21 \text{ Mg}\cdot\text{ha}^{-1}$) (Fig.2a). The highest TN was in the lower depth (30-50 cm) ($2.09 \text{ Mg}\cdot\text{ha}^{-1}$) which it had significant difference with the two upper depths (1.67 and $\text{Mg}\cdot\text{ha}^{-1}1.56$, respectively). The first two depths showed a significant difference with each other (Fig.3b).

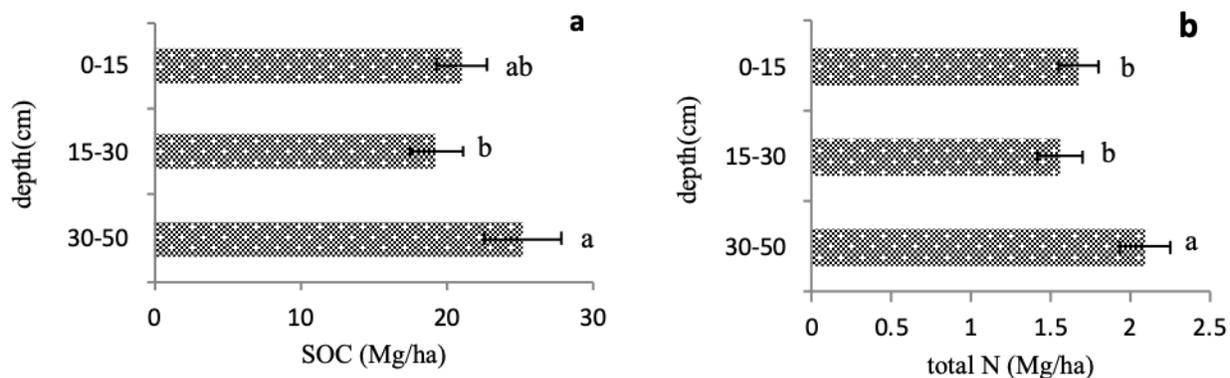


Fig.3 Distribution (mean \pm S.E) of SOC and TN ($\text{Mg}\cdot\text{ha}^{-1}$) sequestration within 0–15, 15-30 and 30-50 cm soil depths. Different letters indicate the significant differences of mean values ($P<0.05$) among the treatments.

3.3. *The quantitative properties of stands*

Some of quantitative properties of stands are presented in Table 2 and Fig 3. Accordingly, the maximum DBH was found in the mixed oak – beech stand, it was significantly different from the other stands. The highest means of total height,

total volume, trunk height, and volume of canopy coverage were observed in pure beech stand. The highest level of basal area was in mixed stand of oak - maple which had statistically significant difference with the other stands.

Table 2. The characteristics (\pm SE) of the Beech, Maple-Beech and Oak-Maple stands.

Stand parameter	Stand		
	beech	Maple-Beech	Oak-Maple
DBH (cm)	17.15 \pm 0.68 ^b	14.89 \pm 0.07 ^c	19.5 \pm 0.16 ^a
Total height (m)	8.76 \pm 0.02 ^a	6.38 \pm 0.03 ^b	6.06 \pm 0.07 ^c
Basal area (m ² /ha)	0.022 \pm 0.0018 ^b	0.019 \pm 0.0003 ^c	0.029 \pm 0.01 ^a
Total volume (m ³ /ha)	0.11 \pm 0.01 ^a	0.068 \pm 0.001 ^b	0.095 \pm 0.001 ^a
Trunk Height(m)	3.24 \pm 0.03 ^a	3.07 \pm 0.30 ^b	2.99 \pm 0.03 ^b
Canopy volume (m ³ /ha)	8.22 \pm 0.76 ^a	7.16 \pm 0.02 ^a	6.83 \pm 0.02 ^a

Values followed by the same letter at the row are not significantly different at $p < 0.05$

The highest amounts of above- and belowground biomass (Fig 4) were 39.18 Mg.ha⁻¹, 11.75 Mg.ha⁻¹, respectively, in pure beech that had no significant difference with mixed oak - maple (34.74 and 10.43 Mg.ha⁻¹

respectively), but they showed significant differences with mixed maple - beech (20.25 and 6.26 Mg.ha⁻¹) stand.

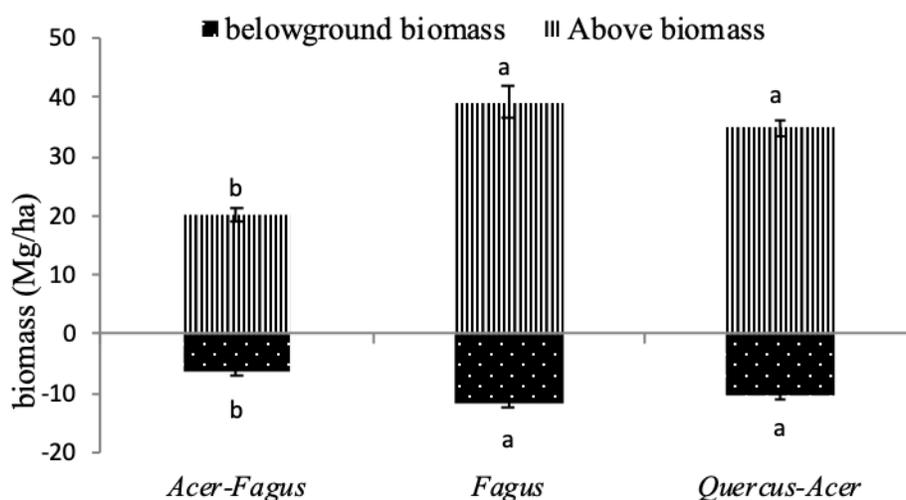


Fig 4. Above- and belowground biomass (mean \pm SE) in the stands. Different letters denote significant differences at $p < 0.05$.

3.4. Carbon sequestration of above- and belowground biomass:

Comparison of carbon sequestration of above- and belowground biomass means were showed in three stands (Fig. 5) The highest carbon sequestration of above- and belowground biomass were in pure beech stand with the numerical values of 59.19 and 87.20 $\text{Mg}\cdot\text{ha}^{-1}$, respectively. The carbon sequestration of aboveground biomass of the beech stand and the mixed oak-beech stand had no statistically significant difference with each other with the numerical value of 17.43 $\text{Mg}\cdot\text{ha}^{-1}$, while the former was significantly different from the mixed maple - beech with the value of 10.53 Mg/ha . The belowground carbon sequestration in two mixed oak - maple (18.5 Mg/ha) and maple - beech (14.3 $\text{Mg}\cdot\text{ha}^{-1}$) stands did not show significant differences.

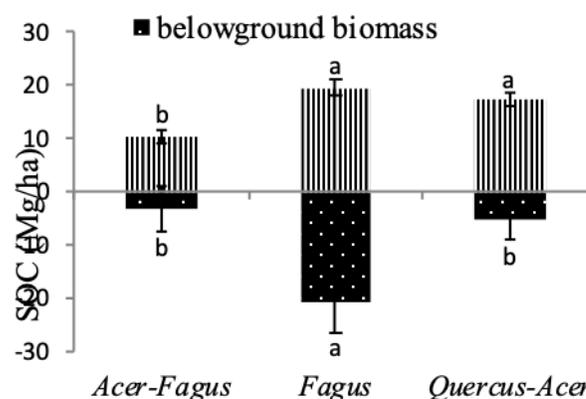


Fig 5. SOC storage in Above- and belowground biomass (mean \pm SE) in the various stands. Different letters denote significant differences at $p < 0.05$.

3.5. Carbon sequestration of the litters:

The carbon sequestration of litters in the three stands investigated showed significant differences (Fig 6). The highest carbon sequestration was found in the forest floor litter in mixed stand of maple - beech (4.11 $\text{Mg}\cdot\text{ha}^{-1}$) which showed significant difference with the two stands of beech (3.49 $\text{Mg}\cdot\text{ha}^{-1}$) and oak - maple (3.51 $\text{Mg}\cdot\text{ha}^{-1}$). The pure and mixed stands of beech and oak - maple did not show

statistically significant differences.

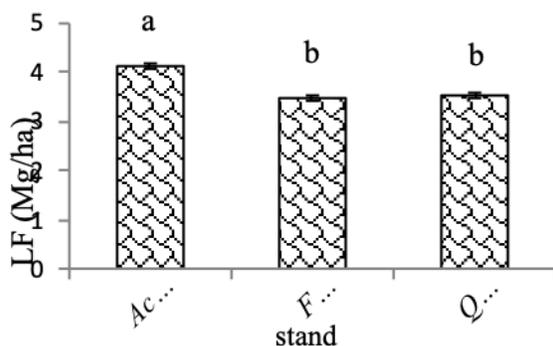


Fig 6. SOC in the litter floor (mean \pm SE) in the stands. Different letters denote significant differences at $p < 0.05$.

Fig. 7 shows the contribution percentage of each carbon pool in the total carbon sequestration of each stand. The contribution of mineral soil in SOC sequestration in the mixed stands was higher than any other ecosystem components. The contribution percentages in the two mixed stands were the same of 50%. But in the pure beech stand, the contribution percentage of SOC was 33%. The highest contribution percentage of belowground biomass was gained in the pure beech stand (32%) which was significant compared to two other stands. The contribution of litter in the total carbon sequestration was 5.7 and 11% in maple - beech, oak - maple and beech, respectively. The highest contribution percentage of aboveground biomass in carbon sequestration was in oak – maple stand (33%), while these percentages were 30%, 29% in beech and maple - beech stands of the total carbon sequestration, respectively.

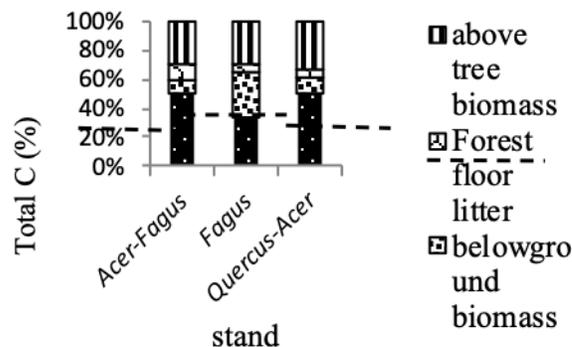


Fig 7. C content of total aboveground tree biomass, belowground biomass, floor litter, and mineral soil in the stands expressed as a percentage of total ecosystems C (dashed line separates above- from belowground C pools).

The total carbon sequestration (the sum of carbon sequestration in the soil, litter, above- and belowground biomass) was indicated in Fig 8. The highest total carbon sequestration in the pure beech stand was with the numerical value of 61.93 Mg.ha⁻¹. The lowest amount of carbon sequestration in the mixed stand of maple-beech was 31.72 Mg.ha⁻¹. The total carbon sequestration in the mixed oak – maple stand was 95/48 Mg.ha⁻¹.

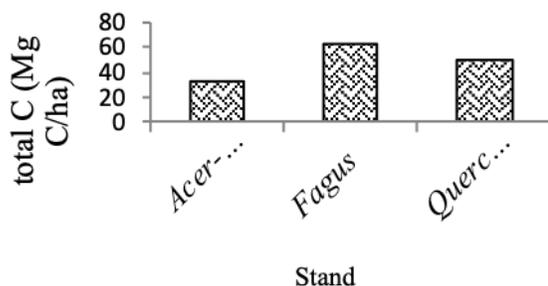


Fig 8. The total C content (aboveground tree biomass, belowground biomass, floor litter, and mineral soil within 0–50 cm depth) in the stands

There was high correlation between SOC and TN in the soil of stands ($r = 0.72$, $p < 0.0001$) (Fig 9).

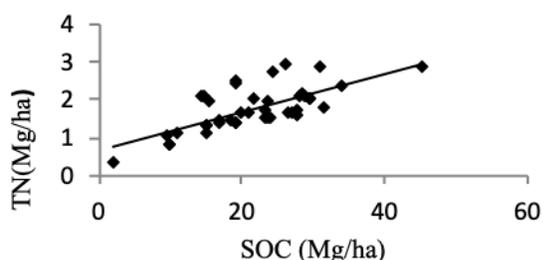


Fig 9. correlation between SOC (Mg ha^{-1}) and TN (Mg ha^{-1}) sequestration in all stands.

4. Discussion

4.1. SOC and TN sequestration

In this study, due to the direct affectability of trees and microorganisms, the upper depths (0-50 cm) were investigated. The stands considered had significant impacts on the SOC and TN.

So far, different reports were published on the subject of "the effects of tree species on the soil nitrogen". Some researchers (Wang et al, 2010) did not achieve in the soil nitrogen of these species, while other scientists (Siddique et al, 2008) differently reported the effects of plantation on the soil nitrogen. Our results indicate the effects of species and stands on TN in the soil profile. The high concentration of nitrogen was observed in the depth of 30-50 cm within all three stands. Lemma and Olsson (2006) also found such a trend in their studies regarding *Pinus patula*. Moreover, they declared the effects of different land uses and species types in different types of soil TN. They reported that the amount of $\text{N}^{\delta^{15}}$ increased with the enhancement of depth. Nadelhoffer and Fry, (1988) stated that the increase of $\delta^{15}\text{N}$ in deep forest soils can be increased by a combination of low bed input with $\delta^{15}\text{N}$ at the surface and isotopic fractionation during OM decomposition. There was high correlation between SOC and TN in the soil of stands ($r = 0.72$, $p < 0.001$)

(Fig 9). Due to this correlation, the highest amount of SOC was found in the 30-50cm depth (Fig2a). Sing and Singh (1993) believed that the accumulation of organic carbon and nutrients in the different depths of soil depended on humus content, canopy coverage and type of species. In addition, the soil microorganisms in the course of decomposition and carbon dioxide emission should not be ignored. The microorganism activities in the surface layer were high, and this happening caused an increase in the respiration and carbon emission so that it resulted in a significant reduction than lower depths.

Uri et al (2012) mentioned that the high fertility of soil in the surface layer (30 cm) and an increase in the rate of respiration make SOC to appear in low amount (29-38% of total carbon).

The results revealed that not only the species types caused to changes in SOC, but also it was effective in its distribution in the soil profile. Lemma, et al (2006) declared that despite the similar management history of *Cupressus lusitanica* and *Pinus patula* stands on the soil, there was noticeable difference in the organic carbon depending on the tree species. Lemenih et al (2004) determined the changes in the soil properties of *Cupressus lusitanica* and *Eucalyptus saligna*, they also concluded that the rate of changes in the soil properties depended on the type of tree species.

4.2. Carbon sequestration of above- and belowground biomass:

Interestingly, the results showed that there was a direct relation between the amount of above- and belowground biomass and carbon sequestration. The high biomass volume has caused a high level of carbon

sequestration in the stands. There was a significant positive correlation between the total volume and the carbon sequestration of biomass ($r = 0.78$, $p < 0.03$). The high contribution of total above- and belowground of carbon sequestration of the forest ecosystems in the beech stand was questionable. Currently, the proportions of carbon accumulation in the soil and biomass are remarkably controversial topics (Uri et al., 2012). It is believed that the forest soil storage often has significant amount of carbon than forest coverage (Peltoniemi et al., 2004).

According to the EC/UN-ECE (2003) report, the forest soil in Europe stored carbon approximately one fifth times more than existing carbon in the trees.

This study presented the fact that the pure beech stand from total carbon stored has saved 62% of carbon in its biomass.

Thus, the contribution of carbon sequestration of biomass in the beech stand was higher than the soil, while in the other stands, contribution of biomass was lower than the soil in total carbon contribution of ecosystem. Uri et al (2012) performed a study on natural stands of *Betula pendula* Roth. which it showed that trees were the most important carbon sinks.

De Wit et al (2006) in southeastern forests of Norway showed that 80% of carbon sinks in the trees and the soil was approximately 20%. Peichl and Arain (2006) for white pine stand (*Pinus strobus*) concluded that the aboveground biomass of trees was the main ecosystems of C pool with aging. Also, these results probably were gained due to the high above- and belowground biomass which it did not have a direct impact on soil carbon sequestration. In other word, high total biomass in stand did not cause high organic

carbon in the soil.

The main reason for the high nitrate concentration in the wet season in 60.87% of the samples compared to the dry season, was more rainfall due to leaching of the previous year's fertilizers and their infiltration into water resources. The highest amount of nitrate in the dry season was related to drinking water of Taleb Gheshlaghi Village (212 mg / l) and the lowest amount of Jamadi Village (11.5 mg / l). In the wet season, the highest values were in the village of Dujjin (264 mg / l) and the lowest in the village of Agbalagh Rostam Khan (9.55 mg / l).

GS + software analysis results showed that the best model for normalized nitrate data is the exponential model. Validation results also showed that conventional kriging method with the lowest RMSE is the most accurate method for interpolation and zoning of nitrate values. Results of interpretation of the maps showed that areas with high nitrate were located in the lowland areas where the dominant irrigation was potato and wheat, and areas with low nitrate were observed in areas with dry farming and pasture - dry farming.

Examination of the elevation map showed that the slope in the region was from northwest to east and center of the plain, which was in line with the map of changes in nitrate levels, which had also decreased from west to east. The concentration of nitrate in these areas was also critical due to the landfill site of Ardebil city near Talib Gheshlagh and Samian villages. The main cause of groundwater pollution in this area is due to leachate infiltration from Ardebil landfill to the aquifer.

4.3. Carbon sequestration of forest floor litter:

The results showed that the lowest contribution of SOC among the various components considered in the forest ecosystems in all three stands was the carbon in the forest floor litter (from 7 to 11%) (Fig 7). The contribution of stands in

this respect was a little different. In this study, the mixed stands (oak - maple and maple - beech) had more contribution to the total carbon sequestration in floor litter than pure stands.

There was the possibility that the leaf production had important contribution to the litter production in the forest floor more than pure beech in the mixed stands. Despite the low contribution of litter to the total organic carbon sequestration in stands, its role should not be ignored from the total carbon stock in the stands ($3.7 \text{ Mg}\cdot\text{ha}^{-1}$, on average).

Uri et al (2012) declared that the significant cause of high carbon in the litter of one of the stands was related to high humidity and poor degradation conditions at the litter in the floor of stand. The soil fertility was low and so the activities of microorganisms were low than other stands in the maple-beech stand. Therefore, due to no degradation, the accumulation of litter happened in the stand floor. The litter production and its decomposition rate had a significant effect on the soil fertility (Pragasari and Parthasarathy, 2005) and it was an important factor by which tree species affected nitrogen and organic matter of the soil (Finzi et al, 1998). As a result, low fertility in the maple-beech stand was associated with the low amount of nitrogen in maple - beech stand (Fig 2b). Singh et al (2004) found that the low rate of litter decomposition reduced nitrogen in the soil of *Albizia procera* stand.

5. Conclusions

Totally, among all stands considered, the pure beech stand presented the highest total carbon sequestration ($61.93 \text{ Mg}\cdot\text{ha}^{-1}$). The high above- and belowground biomass in the beech stand had integral impact on a

rise in the total carbon sequestration compared to the other stands. In other words, the most important issue in this study was the high contribution of biomass in the increase of total carbon sequestration in the beech stand. Moreover, the high correlation of SOC and TN (Fig 9) could be the reason of the affectability of the soil nitrogen in the total carbon sequestration which it in turn may be related to the fertility and degradation activities in the soil. Accordingly, further investigations on this subject are needed.

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Competing Interests

The author declare there is no competing interests, regarding the publication of this manuscript

Author Contributions

Ebrahim Fataei: Proposed the plan, conceived the experiments, analyzed the data, authored or revised drafts of the paper, approved the final draft.

Ethics Statement

Vice Chancellor for Research and Technology, Islamic Azad University, Ardabil Branch

References

- Bauer A, Cole CV, Black AL, (1987) Soil property comparisons in virgin grasslands between grazed and nongrazed management systems. *Soil Science Society of America Journal*, 51: 176–182.
- Birdsey R, Heath I, Williams D, (2000) Estimation of Carbon Budget Model of the United State Forest Sector Advances in Terrestrial Ecosystem Carbon Inventory, Measurements and Monitoring Conference in Raleigh, North Carolina, October 3-5, 51-59.
- De Vries W, Reinds GJ, Gundersen P, Sterba H, (2006). The impact of nitrogen deposition on carbon sequestration in European forests and forest soils. *Global Change Biol.* 12, 1151–1173.
- De Wit HA, Palosuo T, Hysten G, Liski J, (2006) A carbon budget of forest biomass and soils in southeast Norway calculated using a widely applicable method. *Forest Ecology and Management* 225, 15–26.
- Dixon RK, Wisniewski J, (1995) Global forest systems: an uncertain response to atmospheric pollutants and global climate change. *Water Air Soil Pollute.* 85: 101-110.
- EC/UN-ECE, de Vries W, Reinds GJ, Posch M, Sanz MJ, Krause GHM, Calatayud V, Renaud JP, Dupouey JL, Sterba H, Vel HM, Dobbertin M, Gundersen P, Voogd JCH, (2003) Intensive monitoring of forest ecosystems in Europe, 2003 Technical report. EC/UN-ECE 2003, Brussels, Geneva (p. 163).
- Fataei E, Varamesh S, Seiiid Safavian ST, (2018) Effects of afforestation on carbon stocks in Fandoghloo forest area, *Pakistan Journal of Agricultural Sciences*, 55(3): 555-562.
- Finzi AC, Canham CD, Van Breemen N, (1998) Canopy tree soil interactions within temperate forests: species effects on pH and cations. *Ecological Applied*, 8: 447-454.
- Garten JR, Charles T, (2002) Soil carbon storage beneath recently established tree plantations in Tennessee and South Carolina, USA. *Biomass and Bioenergy*. Volume 23, Issue 2, August 2002, Pages 93-102. 109, 165–190.
- Haster RE, Harrison RM, (2010) Carbons capture sequestration and storage. *The royal society of chemistry*. 325 pp.
- Hernandez R, koohafkan P, Antoine J, (2004) Assessing Carbon Stocks and modeling win-win. Scenarios of carbon sequestration through land-use change. 166 pp.
- Houghton RA, (2005) Aboveground forest biomass and the global carbon balance. *Global Change Biol.* 11, 945–958.
- Kothandaraman S, Ahmad Dar J, Sundarapandian S, Dayanandan S, Latif Khan M, (2020) Ecosystem-level carbon storage and its links to diversity, structural and environmental drivers in tropical forests of Western Ghats, India, *Sci Rep.* 2020; 10: 13444.
- Lal R, (2005) Forest soils and carbon sequestration. *Forest Ecology and Management* 220 242–258.
- Lemenih M, Olsson M, Karlton E, (2004) Comparison of soil attributes under *Cupressus lusitanica* and *Eucalyptus saligna* established on abandoned farmlands with continuously cropped farmlands and natural forest in Ethiopia. *For. Ecol. Manag.*, 195(s 1–2): 57–67.
- Lemma B, Berggren D, Nilsson I, Olsson M, (2006) Soil carbon sequestration under different exotic tree species in the southwestern highlands of Ethiopia., *Geoderma* 136(3):886-898.
- Lemma B, Olsson M, (2006) Soil $\delta^{15}N$ and nutrients under exotic tree plantations in the southwestern Ethiopian highlands. *Forest Ecology and Management* 237 : 127–134.

- Long JN, Turner J, (1975) Aboveground biomass of understorey and overstorey in an age sequence of four Douglas-fir stands. *J. Appl. Ecol.* 12, 179–188.
- Losi CJ, Siccama TG, Juan RC, Morales E, (2003) Analysis of alternative Methods for estimating carbon stock in young tropical plantations. *Forest Ecology and Management.* 184: 355–368.
- McDicken KG, (1997) *A Guide to Monitoring Carbon Storage in Forestry and Agro forestry Projects.* Winrock International Institute for Agricultural Development, Forest Carbon Monitoring Program. pp: 91.
- Nadelhoffer KJ, Fry B, (1988) Controls on natural nitrogen-15 and carbon-13 abundances in forest soil organic matter. *Soil Sci. Soc. Am. J.* 52, 1633–1640.
- Oliver GR, Pearce SH, Kimberly MO, Ford-Robertson JB, Robertson KA, Beets PN, Garrett LG, (2004) Variation in soil carbon in pine plantations and implications for monitoring soil carbon stocks in relation to land-use change and forest site management in New Zealand. *Forest Ecol. Manage.* 203, 283–295.
- Olsen SR, Cole CV, Watanabe FS, Dean LA, (1954) Estimation of available phosphorus in soils by extraction with sodium bicarbonate. *USDA Circular No. 939.*
- Peichl M, Arain MA, (2006) Above- and belowground ecosystem biomass and carbon pools in an age-sequence of temperate pine plantation forests. *Agricultural and Forest Meteorology:* 140 51–63.
- Peltoniemi M, Mäkipää R, Liski J, Tamminen P, (2004) Changes in soil carbon with stand age—an evaluation of a modelling method with empirical data. *Global Change Biol.* 10, 2078–2091.
- Powers JS, Schlesinger WH, (2002) Relationships among soil carbon distributions and biophysical factors at nested spatial scales in rainforests of northeastern Costa Rica. *Geoderma.*
- Pragasam LA, Parthasarathy N, (2005) Litter production in tropical dry evergreen forests of south India in relation to season, plant life forms and physiognomic group's current science, 88: 1255-1263
- Sahrawat KL, (1982) Simple modification of the Walkley–Black method for simultaneous determination of organic carbon and potentially mineralizable nitrogen in tropical rice soil. *Plant and Soil* 69, 73–77.
- Raha D, Ahmad Dar J, Kumar Pandey P, Ahmad Lone P, Verma S, Kumar Khare P, Khan ML, (2020) Variation in tree biomass and carbon stocks in three tropical dry deciduous forest types of Madhya Pradesh, India. *Carbon Manage.* 11(2):109–120.
- Siddique I, Engel VE, Parrotta JA, Lamb D, Nardoto GB, Ometto GP, Martinelli LA, Schmidt S, (2008) Dominance of legume trees alters nutrient relation in mixed species forest restoration planting within seven years. *Biogeochemistry,* 88:89-101.
- Singh AN, Raghunathan AS, Singh JS, (2004) Comparative performance and restoration potential of two *Albizia* species planted on mine spoil in a dry tropical region, India. *Ecological Engineering,* 22: 123- 140.
- Singh G, Singh, NT, (1993.) *Mesquite for revegetation of salt lands.* Central Soil Salinity Research Institute. Bulletin. 18: 20-26.
- Uri V, Varik M, Aosaar J, Kanal A, Kukumägi M, Lõhmus K, (2012) Biomass production and carbon sequestration in a fertile silver birch (*Betula pendula* Roth) forest chronosequence. *Forest Ecology and Management.* 267, 117–126.

Wang F, Li Z, Xia H, Zou B, Li N, Liu J, Zhu W, (2010) Effect of nitrogen fixing and non nitrogen fixing tree species on soil properties and nitrogen transformation during forest restoration in southern China. *Soil Science and Plant Nutrition*, 56: 297- 306.

Xiao-Wen D, Shi-Jie H, Yang-Ling H, Yu-Mei Z, (2009) Carbon and nitrogen transformations in surface soils under Ermans Birch and Dark coniferous forests. *Pedosphere*. 19(2): 230-237.

Yue J, Guan J, Deng L, Zhang J, Li G, Du Sh, (2018) Allocation pattern and accumulation potential of carbon stock in natural spruce forests in northwest China, *Peer Journal*, 6:48-59.