A Comparative Study of Soil Carbon Sequestration between a Deteriorated Rangeland and *Pinus eldarica* and *Fraxinus rotundifolia* Stands

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Abstract: Tehran as the capital city of Iran is one of the most populous cities that overpopulation and industrial improvement there have caused the great diffusion of greenhouse gases. However, forestation in deteriorated rangelands of this city can have a high potential to decrease the density of atmospheric CO_2. This research was done in two stands of *Pinus eldarica* and *Fraxinus rotundifolia* and the adjacent deteriorated rangeland as control (blank), in Chitgar forest park of Tehran and soil carbon sequestration content was measured. In addition, the relationship between soil organic carbon (SOC) and some physicochemical factors of soil was determined. Results indicated that *Pinus eldarica* and *Fraxinus rotundifolia* stands caused the increment of soil carbon sequestration around 46.18 and 37.2 tons per hectare, respectively in comparison with adjacent deteriorated rangeland. The content of SOC in two mentioned stands was more in the first layer than that of the second layer but it was opposite in blank (control). The result of stepwise regression showed that sand was the most important factor, affecting SOC. According to the results of correlation analysis, there was a positive significant relationship between SOC and % silt and % sand and a negative significant relation between SOC and %clay and %gravel. The economic values of carbon sequestration increment in mentioned stands were calculated to be 13.9 and 2.5 million dollars, respectively. Our study showed that forestation is an effective land-use option to restore deteriorated lands of this area and have a high potential to alleviate global warming and climate change.

Keywords: Climate change, forestation, soil carbon sequestration, chitgar forest park of Tehran.

1. INTRODUCTION

Fossil fuel usage, deforestation and land use changes through carbon diffusion increasing caused the increment of greenhouse gases density and climate changes in many regions of the world consequently [1-2]. Atmospheric CO2 is the main reason for global warming and climate change, which its density has raised around 31% because of the mentioned reasons since 1750 up to now. Therefore, some methods to decrease the dangers of global warming should be found [3]. Universal concerns about this issue have led to more interest in using trees and forestation to decrease the atmospheric CO2 level [4-6]. Because of forestation, revival and forest stock growth, Onegiga tone carbon is being stored annually [2]. A suggested method to reduce atmospheric CO2 is universal soil carbon store, which contains almost 75% carbon store of land [7,8]. The amount of organic carbon in virgin soil of natural forests is more and the land use change of them causes the SOC loss [9, 10]. Soil can be both as a source and as a store for atmospheric carbon [11]. Soil is the greatest organic carbon store.

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The size of uncultivated and abandoned lands of the world is about a milliard hectare and if the production of these lands is assumed about 12 tones of dry matter annually (equal to 6 tones carbon per hectare annually) about 5 giga tones carbon will be absorbed annually [12]. Furthermore, because of vegetation cover application and tree plantation as forestation we can have carbon storage beside green area creation, wood production and other advantages of forest [13]. The soil carbon content significantly shows the changes with local changes, topography and bedrock or vegetation and previous management. In addition, in time range, the carbon content during vegetation growth season and time of decomposition process can vary in roots, litters and biomass of soil microorganisms [14].

However, Iran is not considered as an industrial country, but because of oil and oil products, which include the main part of export and national gross income it has a great share to introduce pollutant matters and CO2 among them in universal level [15]. In addition, the matter of global warming and atmospheric CO2 increment is a universal problem and it is not limited to a particular country. For this reason, doing researches in this filed in Iran are essential. The current study was aimed to define the potential of soil carbon sequestration of *Pinus eldarica* and *Fraxinus*

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rotundifolia stands in Chitgar forest park of Tehran and comparing these stands with a deteriorated rangeland. The relationship between SOC and some physicochemical factors of soil was also determined in this research.

2. MATERIALS AND METHODS

2.1. Study Area

The study area is located in west of Tehran in the Chitgar forest park with an area about 900 hectares between 51°10' and 51°15' E longitude and 35°42' and 35°45' N latitude. This forest park has been established in 1968 with the aims of air pollution reduction, making a green belt around Tehran, softening the air, making entertainment center and preventing the unsuitable development of city. The density of planted trees is about 800 trees per hectare. Forty five% of total area of park is covered with *Pinus eldarica* and 10% of total area is occupied by *Fraxinus rotundifolia.* The study area is considered as arid Mediterranean climatic region with the mean sea level of 1300 m and mean precipitation of 232 mm [16].

2.2. Sampling Method

The stands of *Pinus eldarica* and *Fraxinus rotundifolia*, with an area of 10 hectares, and a blank (surrounding a deteriorated rangeland) were selected in Chitgar Forest Park. To reduce the border effects, some rows around each stand were not considered [17]. At each stand, ten 5 × 5m plots were selected by random systematic method and in each plot, after removing the litters, soil sampling was performed at two depths of 0~15 cm and 15~30 cm. To minimize the inaccuracy, combination sampling was performed in the way that four soil samples were taken from four corners of plot and then were mixed together [18]. Then at each stand, ten samples were collected from each depth. Samples were dried in open air and after breaking the gravels into small pieces and removing the roots, stones and other trashes were ground by a 2-mm sieve and mixed samples were prepared for the above-mentioned measurement [19].

2.3. Laboratory Method

The percentage of gravel was calculated initially. Afterward, the soil characteristics were studied:

Soil texture was determined by the Bouyoucos hydrometer method [20]. pH was measured using an Orion Ionalyzer Model 901 pH meter in a 1:2.5, soil: water solution. EC was determined using an Orion Ionalyzer Model 901 EC meter in a 1:2.5, soil: water solution. The total nitrogen was measured using a semi-Micro-Kjeldhal technique [21]. Bulk density was determined by clod method gr/cm³ [22]. To measure the organic matter and organic carbon, cold method was applied based on organic carbon oxidation with potassium bicarbonate in a completely acidic environment (H2SO4) according to the following formula [23].

$$8H_2SO_4 + 3C + 2K_2Cr_2O_7 \Longleftrightarrow 2K_2SO_4 + 2Cr_2(SO_4)_3 + 3CO_2 + 8H_2O$$

In addition, soil saturation percentage was measured [24].

2.4. Data Analysis

An analysis of variance (ANOVA) was conducted for all collected data by MSTAT-C program (Michigan State University). The normality of data was assessed by Kolmogrov-Smirnow test and the homogenity of variances was tested by Levene test. According to the normality and variance homogenity of data, ANOVA test was used for the comparison of soil characteristics. For multiple comparisons of means, considering the surrounding deteriorated rangeland as blank, the LSD test was used at a significance level of 5% and all graphs were drawn in Excel.

3. RESULTS

Results indicated that total carbon sequestration of *Pinus eldarica* and *Fraxinus rotundifolia* stands were respectively 57 and 48 Mg ha^{-1} and it was calculated to be 10.82 Mg ha^{-1} in blank. In addition, it was observed that carbon sequestration in forestation area was significantly more than that of deteriorated rangeland and in *Pinus eldarica* stand it was more than *Fraxinus rotundifolia*.

According to the results of variance analysis of soil physicochemical characteristics, gravel, pH, soil saturation percentage, O.C, N, C/N showed significant differences in the studied stands ($p < 0.01$); whereas bulk density, O.C, O.M, N and C/N ($p < 0.01$) and pH and EC ($p < 0.05$) were significant for two considered depths. In addition, the interaction effects of stand and depth, O.C and O.M ($p < 0.01$) and N ($p < 0.05$) showed significant differences (Table **1**).

The comparison of soil physicochemical characteristics showed that gravel, saturation percen-

Table 1: Variance Analyze of Soil Character in Two Depths of 0~15cm and 15~30cm in *Pinus Eldarica*, *Fraxinus Rotundifolia* Stands and Deteriorated Rangeland in Chitgar Forest Park of Tehran with the Interactive Effects of Stand and Depth

	d. f	Gravel %	Bulk density (gr/cm^3)	pH	saturation wet%	Silt %	Sand %	Clay %	O.C %	Om %	EC	N %	C/N
Lot	2	0.165**	0.103	4.19**	0.021**	148.77	1998.69	1127	2.8**	8.4**	0.06	0.04**	1316.7**
Depth	1	0.015	0.288**	0.235*	.0001	87.11	32.1	11.1	0.16**	0.4**	0.25*	0.2**	408.7**
Lot × Depth	2	0.001	0.007	0.045	0.0001	14.11	5.3	7.5	0.083**	0.244**	0.073	0.024*	66.55
Error	30	.012	0.033	0.038	0.002	32.167	73.3	19.8	0.007	0.019	0.035	0.004	33.94
Cv%		32.58	11.03	94	13.24	24.72	16.18	18.09	10.39	10.36	25.9	9.5	27.24

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

Table 2: Comparisons of Mean Character of Soil in *Pinus Eldarica, Fraxinus Rotundifolia* Stands and Deteriorated Rangeland

	Gravel %	pH	saturation wet%	Silt %	Sand %	Clay %	OC %	Om %	N %	C/N
P.eldarica	0.451	6.98	0.387	26.1	30.33	43.4	1.071	1.873	0.057	23.00
F.rotundifolia	0.35	7.58	0.304	20.6	36.08	37.9	1.035	1.75	0.041	30.01
deteriorated rangeland	0.21	8.11	0.246	23.	42.4	35.5	0.217	0.37	0.032	7.22
LSD5%	0.092	0.162	0.089	5.606	6.9	9.4	0.046	0.115	0.021	7.03

Table 3: The Comparisons of Mean Character of Soil in Two Depths of 0~15 cm and 15~30 cm

Depth (cm)	Bulk density (gr/cm^3)	pH	C%	Om%	EC	N%	C/N
0-15	1.5	7.57	0.84	1.46	0.11	0.0478	17.43
15-30	1.7	7.73	0.71	1.22	0.20	0.0319	21.78
LSD%5	0.115	0.132	0.054	0.092	0.12	0.028	5.8

tage, SOC, SOM, N was significantly ($p<0.05$) higher in *Pinus eldarica* as compared to *Fraxinus rotundifolia* and deteriorated rangeland. While Sand and pH in deteriorated rangeland was significantly ($p<0.05$) higher in comparison with *Pinus eldarica* and *Fraxinus rotun*difolia stands. Other properties showed no significant difference between the mentioned stands (Table **2**).

The results of mean comparisons of soil characteristics in two depths of 0~15 and 15~30 cm showed that SOC and N values were significantly higher in the first depth as compared to the second depth (15-30 cm). While, the second depth showed significantly higher bulk density and pH values as compared to the first depth (Table **3**).

Table 4: The Comparisons of Mean Character of Soil in Interactive Effects of Stand and Depth in Chitgar Forest Park of Tehran

Lot × depth	C%	Om%	N%
F.rotundifolia	1.2	2.06	0.049
F.rotundifolia	0.94	1.6	0.026
P.eldarica	1.15	1.9	0.057
P.eldarica	0.9	1.6	0.044
Control	0.19	0.32	0.035
Control	0.2	0.41	0.028
LSD5%	0.095	0.16	0.0104

In addition, the interaction effects of stand and depth on soil physicochemical properties showed that SOC was higher in the first depth of *Pinus eldarica* and *Fraxinus rotundifolia* stands as compared to the second depth, while it was lower in deteriorated rangeland. The first soil depth of *Pinus eldarica* stand had a higher value of N as compared to other depths of stands (Table **4**). The results of regression analysis of organic carbon with soil factors showed that sand was the most important factor effective on SOC content and it singly explained 73.7% of the variance in carbon content (Table **5**).

Table 5: Regression Analyzes of Organic Carbon of Soil (Dependent Variable) and Soil Factors

Equations	R^2
$Y = 1.7 - 3.99 \times 10^{-2} X_1$	73.7

Y = carbon weight ، X_1 = sand.

The results of correlation analysis among measured soil characteristics (Table **6**) indicated that SOC had a positive significant relationship with silt and gravel percentage while it had a negative significant relationship with sand and clay percentage.

4. DISCUSSION

Results showed that forestation in deteriorated rangeland caused considerable increment in soil carbon sequestration. *P.eldarica* and *F.rotundifolia* stands caused the increment of soil carbon sequestration 46.18 and 37.2 Mg ha^{-1}, respectively in comparison with surrounding deteriorated rangeland. The increment of soil carbon sequestration because of forestation and its management have been reported by Stavin and Richard (2005) [25], Kerckhoffs and Reid (2007) [26], and Hu *et al*. (2008) [27]. The amount of SOC increases in long term with vegetation establishment as the changes of SOC is gradually.

Considering the area of the study stands (*P.eldarica*: 405 hectares (45%) and *F. rotundifolia*: 90 hectares (10%) of total area of Chitgar forest park) and by computing the amount of soil carbon sequestration increment per hectare, we can come to the conclusion that two stands of *P. eldarica* and *F. rotundifolia* in comparison with surrounding deteriorated rangeland increase the soil carbon sequestration up to 18703 and 3348 tones, respectively. Results indicated that the amount of soil carbon sequestration in *P. eldarica* stand was around 9 Mg ha^{-1} more than that of *F. rotundifolia* stands. The reason of that can be associated with more litter accumulation in surface and more soil conservation by softwoods in comparison with hardwoods. Cannell and Dewar (1993) [28] showed that softwood plantations increased the superficial litters and through that caused the SOC increment.

This amount of soil carbon sequestration due to forestation with *P.eldarica* and *F.rotundifolia* species

Table 6: Correlation Analyses between Measured Character of Soil in *Pinus Eldarica, Fraxinus Rotundifolia* Stands and Deteriorated Rangeland in Chitgar Forest Park of Tehran

	Gravel %	Bulk density (gr/cm^3)	pH	Saturation wet%	Silt%	Sand %	Clay%	C%	O.M %	EC	N%	C/N
Gravel %	1.00											
Bulk density (gr/cm^3)	0.09	1.00										
pH	-0.55**	-0.12	1.00									
saturation wet %	-0.15	0.04	0.31	1.00								
Silt %	-0.31	0.00	0.22	0.04	1.00							
Sand %	-0.33	-0.09	0.12	-0.03	0.37*	1.00						
Clay %	0.51**	-0.09	-0.30	-0.07	-0.59**	-0.83**	1.00					
C %	0.51**	0.06	0.33	0.09	0.63**	-0.84**	-0.99**	1.00				
O.M %	0.56**	-0.10	-0.63**	-0.11	-0.53**	-0.41**	0.74**	-0.75**	1.00			
EC	0.56**	-0.10	-0.63**	-0.11	-0.53**	-0.41**	0.74**	-0.75**	1.00**	1.00		
N %	-0.27	-0.50*	0.34	0.24	0.44	-0.44	0.34	-0.12	-0.12	-0.02	1.00	
C/N	0.40	0.58*	-0.54*	-0.58*	-0.58*	0.78**	-0.77**	0.66**	0.66**	-0.19	-0.74**	1.00

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

was much higher than what reported by Nosseto *et al*. (2006) [29]. Because they concluded that forestation with *P. ponderosa* in rangelands caused 50% carbon sequestration increment, and the reason of that can be related to deterioration of rangeland, considered in this study. In this study, it was observed that the SOC content in the first layer of soil at forestation stands was more than that of the second layer but in deteriorated rangeland, the amount of SOC in the second layer was higher as compared to the first layer. It can be related to the high density of litter in depth of 0~15 cm at forestation stands. Frank *et al*. (1995) [30] found that SOC in first layer was more than second layer. Paul and Clark (1996) [31] also attained the same results in this case. In addition, Woomer *et al*. (2004) [32] studied the amount of stored carbon in soil and plant in Senegal and showed that about 60% of SOC was stored in the depth of 20 cm of soil surface. Regarding to severe surface erosion in deteriorated rangeland in comparison with the planted stands of *P. eldarica* and *F.rotundifolia,* this issue can be related to carbon loss due to surface erosion.

The results of regression analysis (Table **5**) showed that sand was the most important factor effective on SOC content. In addition, the results of correlation analysis (Table **6**) showed the relation between SOC and % gravel, clay, silt and sand. In this case, the results of Garten (2002) [33] indicated that SOC was correlated with organic matter and silt and clay percentage. They also reported that the soils with more sand and less primary carbon store had more capacity for carbon sequestration. Furthermore, [34] observed a relation between soil texture and biomass carbon and then SOC storage. In addition, the SOC was under the influence of cation exchange and soil texture and density [35]. Borchers and Perry (1992) [36] observed that soils with gravel content had less organic carbon in comparison with silty and sandy soils. The ratio of organic carbon and carbon storage capacity and quality are related to the action litter. Soil carbon sequestration can be increased mainly through forestation and accurate land providing, sufficient soil drainage, the growth of species with high NPP (net primary product) and water and soil resources conservation [37].

Refining atmospheric carbon using the artificial methods requires high expenses in such a manner that in USA these expenses were estimated to be 100~300 dollars [38]. Each of *P. eldarica* and *F. rotundifolia* stands increased the soil carbon sequestration up to 18703 and 3348 tons, respectively in comparison with surrounding deteriorated rangeland. The calculated amounts were respectively 69201 and 12388 tone of atmospheric CO_2 that their economical values were respectively 13.9 and 2.5 million dollars. If the amount of carbon sequestration in over above and belowground biomass of trees be added to the mentioned number, the economical importance of forestation plans with respect to carbon sequestration will be more considerable. Likewise, regarding that the main part of soil carbon was stored in depth of 0~15 cm, this process greatly helped to increase the fertility and improve soil hydrologic system and also to prevent the erosion. The improvement of soil and water quality, decreasing nutrients loss, increasing water conservation and more crop production are the benefits of carbon sequestration in soils [9, 10].

5. CONCLUSION

From the results of this research it can be deduced that efforts for carbon sequestration management not only cause the fundamental changes in climate change but also will have direct and great effects on soil qualities and consequently the quality of forestation ecosystems, environment and biodiversity.

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