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Soil Carbon Sequestration and Understory Plant Diversity under Needle and Broad-leaved Plantations (Case Study: Shahed Forest Park of Malayer City)

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ABSTRACT

Aims In relation to global climate changes, the issue of how forest ecosystems could affect biomass and soil carbon sequestration is essential.
Materials & Methods To do this research, ailanthus (*Ailanthus altissima* Mill.) and Arizona cypress (*Cupressus arizonica* Greene) plantations were selected each one with an area of 20 hectare in forest park of Malayer, Western Iran. An adjacent area with no tree was selected as control. In each of the plantations and control area, ten plots of 20 × 20 m^2 deployed and biomass of trees, biodiversity indices (Shannon–Wiener, Simpson, Menhinick, and Margalef indices), and carbon sequestration of aboveground tree biomass, belowground biomass, leaf litter, grass, and soil were measured.
Findings The results showed that the carbon sequestration in Arizona cypress plantation (32.32 t ha^{-1}) and the soil under it (11.15 t ha^{-1}) was higher than that in ailanthus plantation and the soil under it (17.99 and 7.6 t ha^{-1}, respectively). However, the soil carbon sequestration under both plantations was higher than that in control area (5.28 t ha^{-1}). According to the results, it was found that herbaceous understory of ailanthus plantation had stored carbon more than arizona cypress plantation. Furthermore, the results indicated that there is a significant difference between two plantations from the point view of the understory plant diversity (Menhinick index in ailanthus and Arizona cypress plantations was 3.17 and 2.44, respectively).
Conclusion This research confirms that plantation with Arizona cypress tree is more efficient in soil and tree biomass carbon sequestration than plantation with ailanthus trees. Furthermore, according to the results, the understory plant richness in ailanthus plantation was higher than that in arizona cypress.

Keywords Biodiversity Indices; Organic Carbon; Plantation; Tree Biomass

CITATION LINKS

[1] Biodiversity and carbon stocks in different ... [2] Reforestation makes a minor contribution to ... [3] Managing temperate forests for carbon ... [4] Trade-offs in carbon storage and ... [5] Organic carbon in soil physical ... [6] An ecosystem approach to biodiversity ... [7] Agroforestry as a strategy for ... [8] Tree species' influences on soil carbon ... [9] Effects of tree species mixture ... [10] Carbon sequestration in the ... [11] Carbon storage in successional ... [12] Assessing carbon sequestration impacts ... [13] EIntelligent approaches to analysing ... [14] Relationship between carbon stock ... [15] The relationship between biodiversity ... [16] Investigating the relationship of some ... [17] Introduction to the economic geology ... [18] Estimate atmospheric carbon ...[19] Assessing carbon stocks and modeling ... [20] Changes in soil carbon storage ... [21] Soil carbon sequestration under ... [22] Guidelines for measuring carbon ... [23] Measuring biological ... [24] Investigation on soil carbon sequestration and understory biodiversity of hard wood and soft wood plantations of ... [25] The influence of land-use change ... [26] Statements at the third strategic thought meeting ... [27] Estimate the carbon sequestration ... [28] A comparison of soil carbon ... [29] Carbon sequestration and its ... [30] Variations in type of vegetal cover ... [31] China's environment in a globalizing ... [32] Wood carbon content of tree species in Eastern China: Interspecific variability and the importance of the ... [33] Plant litter: Decomposition, humus formation ... [34] Correlation between soil organic matter, total organic matter and water content ... [35] Relationships between of carbon, nitrogen ... [36] Soil organic carbon pool under ... [37] Investigation on forest herbaceous plant covers in softwood and hardwood ... [38] The role of native species plantations in recovery of understory Woody diversity in degraded pasturelands ...

Introduction

Over the centuries, exacerbation of human activities has led to an increase in carbon dioxide (CO_2) concentration of more than 400 ppm in the atmosphere, affecting the structure and performance of terrestrial ecosystems.[1] CO_2 is the most important greenhouse gas that causes climate change on a global scale.[2] Deforestation and development of forest management plans have led to an increase in global warming.[3] Deforestation is the world's second largest source for greenhouse gas emissions,[4] whereas a afforestation is one of the most important strategies for regulating climate change on the planet[1,4] and may increase carbon and nitrogen storage in soil by making changes in soil, water, land reclamation, and wood supply.[5] Several studies have investigated the effects of plant species diversity on soil fertility regarding carbon sequestration. The findings of Potvin *et al.*[6] and Nair *et al.*[7] indicated that tree species blending in afforestation projects had effects on the carbon reservoirs and soil carbon cycle. Plantation types can also play a major role in the carbon sequestration.[8] According to Wang *et al.*,[9] the effects of the plantation on the accumulation of soil carbon can be affected by litter quality and the status of soil nutrient elements. It was reported that the potential of carbon sequestration was higher in trees leaves than it in the soil underneath the trees in a plantation with tropical trees in the Western Iran.[10] Previous studies have indicated that the low fertility of soil limits soil carbon sequestration.[5] Marín-Spiotta and Sharma[11] analyzed 81 studies in tropical forests and proposed that the role of climate in carbon sequestration was more important than the forest age. Furthermore, the type of plantation had no significant effect on soil carbon stocks. Goodarzi *et al.*[12] reported that the plantation managements had a significant effect on the carbon sequestration of the species eldarica pine (*Pinus eldarica*) and Arizona cypress (*Cupressus arizonica*). Similar to these species, rangeland covers have a high potential for carbon sequestration in comparison to bare areas. From the point view of carbon sequestration potential, Arizona cypress had a higher rate than eldarica pine. Parvizi *et al.*[13] reported that the carbon sequestration and degradation of it controlled by management factors (especially, tillage and crop residue scenario parameters, and also rotation parameters).

Over the past decades, biodiversity conservation has been the main objective of international conventions, governments, non-governmental organizations, local communities, and communities,[1] and in many studies, the inextricable linkage between climate change, deforestation, forest degradation, and biodiversity is mentioned.[14] In some ecosystems, biodiversity by improving the persistence and fertility of soil increases soil carbon stocks.[15] It should be noted that there is still no clear link between biodiversity and carbon sequestration and there is no apparent information on how biodiversity impacts carbon sequestration.[1,4] Under the current conditions, with regard to biodiversity threats, such as global warming, plantation is important for forest managers. As by choosing appropriate strategies for afforestation projects, they can play a significant role in mitigating and reducing global warming. We hypothesized that ailanthus plantation and the soil under it had more carbon sequestered than Arizona cypress plantation and also understory diversity of ailanthus plantation is higher than Arizona plantation.

This study investigated the carbon sequestration of tree and herbaceous biomass as well as in soil under plantations of evergreen (*C. arizonica* Greene) and broad-leaved (*Ailanthus altissima* Mill.) afforestation. Furthermore, the herbaceous understory diversity was investigated in plantations.

Materials & Methods

Study area

This study was conducted at the afforested area of Shaheed Park (301829.52–303795.16 E and 379264.01–3794069.78 N), Malayer, Hamadan Province, Western Iran. The climate in this region is typically semi-arid. The mean annual precipitation is 354.7 mm and means annual temperature is 13.3°C (from 1997 to 2015). The soil is deep with medium texture and prophylactic development of soil is low.[16] In terms of geologic age, the studied area belongs to the Jurassic, Cretaceous and Pleistocene courses.[17] Afforestation operations began with 10 hectares in 1990 and gradually increased up to 150 hectares with *C. arizonica*, *Thuja orientalis*, *Ailanthus altissima*, *Fraxinus rotundifolia*, *Pinus nigra*, *Pistacia atlantica*, *Ulmus carpinifolia*, *Morus alba,* and *Celtis australis*. Understory vegetation in this region is highly dominated by the Asteraceae, Rosaceae, Apiaceae, Fabaceae, and Poaceae herbaceous plants family.[16]

Inventory of plant biomass

In 2016, approximately 20 hectares for each plantation of ailanthus and arizona cypress were selected. The bare area was selected as a control adjacent to the plantations. 10 quadratic plots, each of 400 m^2 (20 m × 20 m), were established in each of the plantations and control area. The height (H) and diameter at breast height (DBH) for all trees, , were measured for each inventory. Measurement of herb biomass was carried out in 10 subplots (1 m × 1 m) around the main quadrat and harvested all above- and below-ground biomass of grass and understory.[18] All samples were taken to the laboratory and oven-dried at 65°C to obtain a constant weight for biomass estimation. Litter mass was collected in 1 m × 1 m baskets. Four baskets were used for litter mass collection for each quadrat.

Soil sampling and analysis

The soils were sampled with a corer (with diameter 80 mm)[19] at 0–30 cm depths from each ten quadrats. Plant residues and roots were removed by hand. Then, the soil sample was sieved using a 2 mm mesh net and air-dried for analysis of physicochemical properties. Physicochemical characteristics of soil measured using standard methods. Soil organic carbon (SOC) was calculated using the Mann[20] relationship (SOC = 0.58 × SOM).

Soil carbon sequestration (t ha^{-1}) was calculated by applying the Equation (1):

$$Cs = 10000 \times \%OC \times BD \times E \quad (1)$$

Where Cs is the organic carbon (kg ha^{-1}), OC is the concentration of organic carbon, BD is the bulk density (g cm^{-3}), and E is the thickness of soil horizon (cm).[21]

Aboveground tree biomass (AGTB)

AGTB was calculated by applying the Equation (2):

$$AGTB = 0.112 \times (\rho D^2 H)^{0.916} \quad (2)$$

Where AGTB is in kg, ρ is the wood specific gravity (g cm^{-3}), D is the tree DBH (cm), and H is the tree height (H). The carbon of AGTB (C_{AGTB}) can be calculated using the Equation (3) (22).

$$C_{AGTB} = AGTB \times 0.4 \quad (3)$$

Belowground biomass (BB)

BB can be considered as 20% of AGTB. The carbon of BB (C_{BB}) can be calculated by the Equation (4).[22]

$$C_{BB} = BB \times 47\% \quad (4)$$

Leaf litter, herbs, and grass biomass (LHG)

Biomass of LHG was estimated by collecting and weighing fresh field samples including fallen leaves, weeds, and plants in the study area. Then, they were transferred to the laboratory dried for 12 h and weighed again. Finally, samples were placed in the oven for 48 h at 65°C and their weights were measured (dry weight). Carbon in the LHG was calculated using the following Equations (5) and (6).[22]

$$LHG = Wfield \times \frac{Wsubsample\ dry}{Wsub\ sample\ wet} \times \frac{1}{1000} \quad (5)$$

$$C_{LHG} = LHG \times 47\% \quad (6)$$

Where Wfield is the weight of fresh field samples including fallen leaves, weeds, and dry plants (g), Wsubsample dry is the dry weight in oven, containing fallen leaves, weeds, and plants which transferred to the laboratory (g), and Wsubsample wet is the fresh weight of fallen leaves, weeds, and plants which transferred to the laboratory (g).

Total carbon sequestration

Carbon stocks in the AGTB, BB, and LHG were calculated using the following Equation (7):

$$C_{AGTB}+C_{BB}+C_{LHG} \quad (7)$$

The total carbon sequestrated (TCS) was calculated by the Equation (8):

$$TCS = Cs+C_{AGTB}+C_{BB}+C_{LHG} \quad (8)$$

Understory biodiversity indices measurement

To the measurement of biodiversity indices, number and types of herbaceous species in each plantation were identified. Biodiversity formulas (Menhinick and Margalef species richness and Shannon–Wiener and Simpson diversity) were used to calculate the indices of biodiversity [Table 1].[23-26]

Data analysis

The results of Shapiro–Wilk test showed that the soil carbon sequestration and biodiversity indices data were normal ($P < 0.05$). The homogeneity of data was confirmed by Levene test. One-way (ANOVA) and multiple comparison analysis (Duncan) were employed to test the effect of plantation type on soil carbon sequestration and understory biodiversity in each plantation. Independent *t*-test was used to compare the amount of carbon uptake (ground and underground biomass) in the evergreen broad-leaved plantation. Pearson analysis was applied to test the correlation between SOC with traits of soil in both Arizona cypress and ailanthus plantations. The relationship between the carbon stocks and between carbon stocks and species richness was investigated using regression analysis and Pearson's correlation coefficients. Furthermore, Pearson analysis was used to determine whether there is a correlation between SOC and traits of soil in two plantations. Statistical significance was determined at $P < 0.05$. All analyses were performed with the SPSS Ver. 22 software.

Table 1: Formulas used to calculate the indices of biodiversity

Formula	Indicators
$D_{Mn} = \frac{S}{\sqrt{N}}$	Menhinick species richness index
$D_{Mg} = \frac{S-1}{\ln N}$	Margalef species richness index
$H' = -\sum_i p_i \ln(p_i)$	Shannon–Wiener diversity index
$\lambda = 1 - \sum_i p_i^2$	Simpson diversity index

S = Number of species, *Pi* = The percentage of canopy cover of i species ratio to the total percentage of canopy cover of total species, H'= Shannon – Wiener index, H'_{max} = The maximum possible amount of Shannon–Weiner

Findings

Above- and below-ground and soil carbon stocks

Based on the results of the Duncan test grouping, it was found that there was a significant difference in soil carbon sequestration in all three study areas ($P < 0.05$) so that the ailanthus plantation (11.15 t ha^{-1}) in comparison with the Arizona cypress (6.7 t ha^{-1}) and the control area (5.28 t ha^{-1}) had the highest soil carbon sequestration. The value of C_{AGTB} was significantly ($P < 0.05$) higher in the Arizona cypress (26.17 t ha^{-1}) in comparison with ailanthus (14.57 t ha^{-1}). The value of C_{BB} was significantly higher ($P < 0.05$) in Arizona cypress plantation (6.15 t ha^{-1}) compared to ailanthus plantation (3.42 t ha^{-1}). There was no significant difference in C_{LHG} between Arizona cypress (27.22 t ha^{-1}) and ailanthus (21.3 t ha^{-1}) [Figure 1].

Correlation analysis of soil properties

The correlation analysis between SOC and some of the measured traits of soil in both Arizona cypress and ailanthus plantations showed that SOC had a significant positive correlation with percentage of silt and a significant negative correlation with clay, sand, and acidity [Table 2].

There were significantly positive correlations between different carbon stocks. Except for the correlation between aboveground carbon and soil carbon stocks (adjusted $R^2 = 0.6143$, $P < 0.05$), the relationship, though significant, was weaker for the others (Figure 2, adjusted $R^2 = 0.2087$, $P < 0.05$ for aboveground C stock and LHG C stock and adjusted $R^2 = 0.3444$, $P < 0.05$ for soil C stock and LHG C stock). In addition, there were clear correlations between species richness and biomass C stocks. The relationships for species richness are presented in Figure 2. The relationships between carbon stocks and species richness were significant but were not as strong as for the aboveground carbon stock (adjusted $R^2 = 0.1587$, $P < 0.05$ and adjusted $R^2 = 0.4485$, *P*

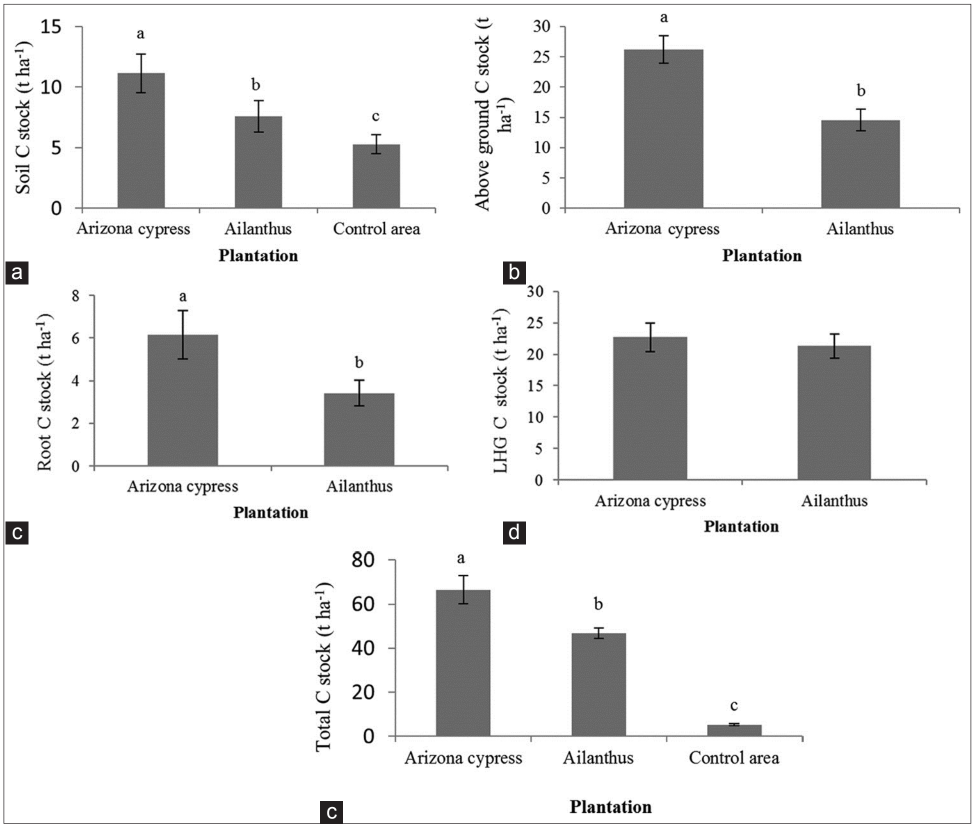

Figure 1: Variation of carbon stocks in soil (a), aboveground (b), roots (c), leaf litter, herbs, and grass (d) and total carbon (e) stocks across plantations and control area by ANOVA and Independent *t*-test. Bars given different letters are significantly different ($P < 0.05$)

Table 2: The correlation between soil organic carbon and traits of soil in two plantations

Parameter	Acidity	The electrical conductivity	Organic matter	Organic carbon	Bulk density	Silt	Clay	Sand
Acidity	1							
The electrical conductivity	0.68	1						
Organic matter	−0.68	−0.84	1					
Organic carbon	−0.76*	−0.79	0.99**	1				
Bulk density	0.88*	−0.35	0.48	0.52	1			
Silt	0.4	−0.79	0.72*	0.75*	−0.28	1		
Clay	0.79*	0.2	−0.54*	−0.39*	0.89	0.28*	1	
Sand	−0.18*	−0.85	−0.57*	−0.47*	−0.13	−0.94*	−0.56*	1

*and **indicate significant differences ($P < 0.05$ and $P < 0.01$, respectively)

< 0.05, respectively, for LHG C stock and soil C stock with species richness).

Plant diversity

According to Table 3, it was found that 70 species of grasses are present in 18 herbal families in the study area.

The calculation of estimated understory biodiversity indices within the two plantations and the control area showed that the ailanthus plantation was the highest as compared to the Arizona cypress and the control area. There is a significant difference between two plantations from the point view of the Menhinick index. The results also showed that there was a significant difference between the biodiversity indices in the ailanthus and control area [Table 4].

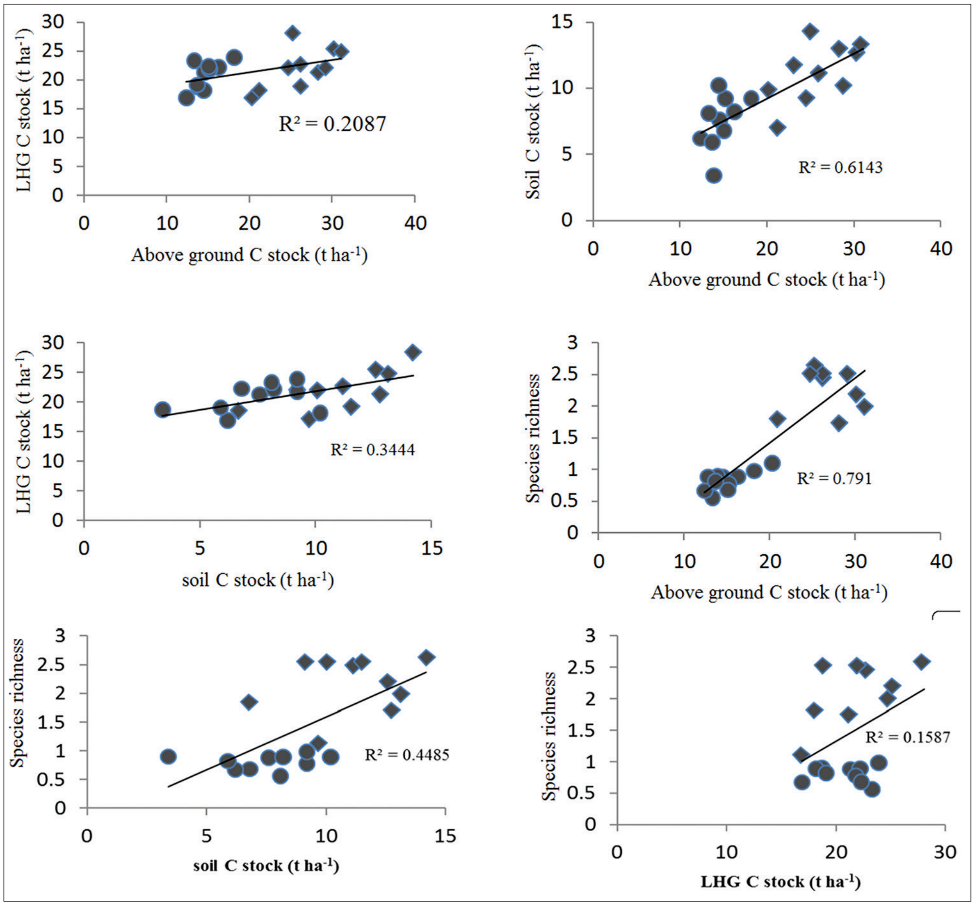

Figure 2: Relationships between different carbon stocks (t ha^{-1}) and between carbon stocks and species richness (n = 10 and $P < 0.05$). Symbols are for Arizona cypress (♦) and ailanthus (●) by Pearson's correlation coefficients

Discussion

The results of this study showed that forests with adaptable tree species have a high ability to treat atmospheric carbon so that the Arizona cypress and ailanthus plantations had a higher carbon content in the soil, with 11.11 and 7.7 t ha^{-1}, respectively, than the bare land (5.28 t ha^{-1}). Further studies (4, 5, 6, 9, 11, 18, 24, 25, 26) have pointed to the role of trees in carbon sequestration. Different tree species have a different capacity for carbon sequestration. Comparison of carbon sequestration of ailanthus and Arizona cypress plantations showed that evergreens stored more carbon in soils under it. This finding was consistent with the results of Hicks *et al.*,[15] Abdi,[27] Nobakht *et al.*,[28] and Azadi *et al.*[24] The findings of Azadi *et al.*[24] indicated that the accumulation of needles not only can prevent the loss of soil carbon but also can increase its uptake. Apparently, the higher amount of soil C and N in the broad-leaved plantations is a result of the higher activity of earthworms and other invertebrates for mixing soil and incorporating large amounts of organic matter into the soil. Unfortunately, except for a few plant species, there is not enough knowledge about chemical compounds (such as lignin and tannin) that regulate soil organic matter in rangelands, agricultural lands, and forests, and as long as this awareness and knowledge, it is not possible to accurately determine the role of tree species in soil carbon sequestration.[29] According to Dinakaran and Krishnayya,[30] trees have a high capacity for soil carbon sequestration compared to other vegetation. Furthermore, trees with a litter of different chemical composition (lignin and cellulose)

Table 3: The list of herbaceous species in the studied plantation and non-afforested area

No.	Scientific name	Family	No.	Scientific name	Family	No.	Scientific name	Family
1	*Chaerophyllum macropodum*	Apiaceae	25	*Silen albescens*	Caryophyllaceae	49	*Helianthemum ledifolium*	Cistaceae
2	*Ferula angulata*	Apiaceae	26	*Adonis aestivalis*	Runanculaceae	50	*Gundelia tournefortii*	Asteraceae
3	*Lapsana communis*	Asteraceae	27	*Centaurea virgata*	Asteraceae	51	*Acanthophyllum microcephalum*	Caryophyllaceae
4	*Frankenia sp.*	Frankeniaceae	28	*Echinophora platyloba*	Asteraceae	52	*Alhagi camelorum*	Fabaceae
5	*Euphorbia cheiradenia*	Euphorbiaceae	29	*Ajuga chamaecistus*	Lamiaceae	53	*Ziziphora teniure*	Lamiaceae
6	*Euphorbia macroclada*	Euphorbiaceae	30	*Achillea millefolium*	Asteraceae	54	*Onosma chrysochaetum*	Boraginaceae
7	*Euphorbia szovitsii*	Euphorbiaceae	31	*Eryngium billardieri*	Apiaceae	55	*Achillea tenuifolia*	Asteraceae
8	*Cousinia pichleriana*	Asteraceae	32	*Astragalus effuse*	Fabaceae	56	*Astragalus parrowianus*	Asteraceae
9	*Cynodon dactylon*	Poaceae	33	*Astragalus orientalis*	Fabaceae	57	*Cerasus microcarpa*	Rosaceae
10	*Phlomis olivieri*	Lamiaceae	34	*Astragalus brachydontus*	Fabaceae	58	*Echinops ecbatanus*	Asteraceae
11	*Onopordon leptolepis*	Asteraceae	35	*Alyssum lanigerum*	Brassicaceae	59	*Scrophularia sp.*	Scrophulariaceae
12	*Ixiolirion tataricum*	Amaryllidaceae	36	*Cephalaria sp.*	Dipsacaceae	60	*Eryngium bungei*	Apiaceae
13	*Gundelia tournefortii*	Asteraceae	37	*Cirsium congestum*	Asteraceae	61	*Sanguisorba minor*	Rosaceae
14	*Kochia prostrata*	Chenopodiaceae	38	*Cichorium intybus*	Asteraceae	62	*Trigonella melanotricha*	Fabaceae
15	*Minuartia meyeri*	Caryophyllaceae	39	*Cardus pycnocephana*	Asteraceae	63	*Rochelia disperma*	Boraginaceae
16	*Dianthus orientalis*	Caryophyllaceae	40	*Bapleurum geradii*	Apiaceae	64	*Tanascetum pinnatum*	Asteraceae
17	*Poa bulbosa*	Poaceae	41	*Anthemis odontostephana*	Asteraceae	65	*Allium atroviolaceum*	Alliaceae
18	*Stipa barbata*	Poaceae	42	*Centaurea aucheri*	Asteraceae	66	*Erysimum crassipes*	Brassicaceae
19	*Xeranthemum longipapposum*	Asteraceae	43	*Centaurea persica*	Asteraceae	67	*Bromus tectorum*	Poaceae
20	*Stachys inflata*	Lamiaceae	44	*Launaea sp.*	Asteraceae	68	*Allium scabricapum*	Alliaceae
21	*Tragopogon graminifolius*	Asteraceae	45	*Vicia peregrina*	Fabaceae	69	*Acroptilon repens*	Asteraceae
22	*Senecio vernalis*	Asteraceae	46	*Prangos acaulis*	Apiaceae	70	*Anemone biflora*	Runanculaceae
23	*Scabiosa sp.*	Dipsacaceae	47	*Papaver argemone*	Papaveraceae			
24	*Rosa persica*	Rosaceae	48	*Lactuca serriola*	Asteraceae			

compared to the grasses, they decompose later and consequently increase the capacity of carbon reserves.[29] This was observed only in the results of the Arizona cypress

Table 4: Comparison of the biodiversity indices (M ± SE) in the studied plantations and the control area

Index	Arizona cypress	Ailanthus	Control area	*P*- value
Shannon-Wiener	2.04 ± 0.027 ab	2.33 ± 0.059 a	2.01 ± 0.034 b	0.000
Simpson	0.86 ± 0.016 ab	0.88 ± 0.02 a	0.82 ± 0.013 b	0.000
Menhinick	2.44 ± 0.103 b	3.17 ± 0.078 a	2.00 ± 0.058 c	0.000
Margalef	1.52 ± 0.043 a	1.89 ± 0.051 a	1.06 ± 0.032 b	0.000

Values given the different letters are significantly different ($P < 0.05$, ANOVA). SE: Standard error

plantation (C_{AGTB} and C_{LHG} were 32.32 and 24.2 t ha^{-1}, respectively), which was consistent with the results of Goodarzi *et al.*[12] However, in ailanthus plantation, due to the high content of herbaceous species richness, the situation was completely different so that herbaceous cover with 21.3 t ha^{-1} had a higher carbon-storing capability than ailanthus trees (17.99 t ha^{-1}). Decomposition rates of litters in broad-leaved plantation stimulate microorganisms, and as a result, cause more carbon sequestration in LHG.[31] Liu and Diamond[31] proposed that further return of litter to the forest floor would increase the microbial respiration of the soil. The results of the carbon sequestration of the AGTB in the plantations showed that Arizona cypress stores more carbon in its biomass than ailanthus. According to Thomas and Malczewski,[32] stems of trees, in comparison to other organs, save more carbon, and in this regard, the evergreens are superior to the broad-leaved trees. trees; because the lignin content of the needles is higher than in litter from broad-leaved trees.[33] According to the results of correlation between SOC and some of the measured traits of soil, there is a significant negative correlation between SOC and clay content as also suggested by Varamesh *et al.*[18] However, Azlan *et al.*[34] and Sakin[35] researches showed that clay has an important role in preserving of carbon stocks preventing the microbial degradation of carbon. Therefore, unlike sand, it increases the carbon content of the soil. However, in agreeing with the results of this study, Jimenez *et al.*[36] reported that if soil sand content exceeds 80%, it could play a more effective role in the loss of SOC and reduce the amount of carbon sequestration in the soil. The increase of soil organic matter causes an increase in the activity of soil microorganisms, resulting in accelerating the CO_2 emission. With increasing CO_2 gas, more carbonic acid is produced, which reduces the acidity of the soil. Increasing the diversity and richness of the species in the understory is one of the main causes of soil carbon uptake.[4] Dayamba *et al.*[1] have reported a significant negative correlation between SOC content and soil bulk density. The soils with lower bulk density increased root growth and carbon accumulation.[1] However, in our study, there was no significant correlation between the two variables. This also could help the significant correlation observed between belowground and soli carbon stocks in two plantations. The significant correlation was found between the different carbon stocks and species richness. Figure 2 shows that the relationship between aboveground and soil carbon stock was even relatively strong (R^2 = 0.6143). Various studies have investigated biodiversity of herbaceous species under evergreen and broad-leaved plantations forests.[24] Similarly, the findings of Ashrafi *et al.*[37] and Azadi *et al.*[24] indicated that the afforestation with evergreen trees, such as Arizona cypress, decreases herbaceous species diversity. Unlikely, Cusack and Montagnini[38] reported that herbaceous species diversity under Turkish pine plantations and in non-afforested area was higher than it in broad-leaved plantations.

According to the Dayamba *et al.*,[1] establishing a diverse vegetation cover is an impressive strategy for carbon sequestration in soil and vegetation. A range of environmental factors such as soil, disturbance, and climate influence the carbon biomass and biodiversity relationships.[1] However, our findings show that there is a supporting reason for biodiversity conservation because biodiversity will conserve carbon pools.

Conclusion

In general, the present study, by investigating the tree, soil, and grass carbon sequestration in evergreen and broad-leaved plantations, determined that the carbon sequestration of Arizona cypress trees and also the soil under it was higher than those of ailanthus trees. The grass cover under the ailanthus trees has saved more carbon than the trees. Furthermore, the richness of the herbaceous under the ailanthus plantation was higher than that under the Arizona cypress. Acquiring knowledge and information about the efficiency of evergreen plantation, especially in semi-arid regions of the country, can enable forest managers to select appropriate tree species, and therefore, help them by applying the best ecological approach, and reduce the effects of climate warming.

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ترسیب کربن خاک و تنوع زیرآشکوب در جنگل‌کاری‌های سوزنی و پهن‌برگ (مطالعه موردی: پارک جنگلی شاهد ملایر)

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چکیده

اهداف: در ارتباط با موضوع گرمایش جهانی، این مساله که بوم‌سازگان جنگلی چگونه می‌توانند بر ترسیب کربن خاک و ذی‌توده اثر بگذارند، بسیار ضروری است.

مواد و روش‌ها: برای انجام این تحقیق، جنگل‌کاری‌های عرعر (*Ailanthus altisimma* Mill.) و سرو نقره‌ای (*Cupressus arizonica* Greene) هرکدام با مساحت حدود ۲۰ هکتار انتخاب شدند. هم‌چنین منطقه عاری از درخت نیز در مجاورت توده‌های مورد بررسی به عنوان قطعه شاهد انتخاب شد. در هر کدام از توده‌های مورد بررسی و منطقه شاهد، ده قطعه نمونه ۲۰×۲۰ مترمربعی مستقر و در داخل قطعات نمونه ذی‌توده درختان، شاخص‌های تنوع زیستی (شاخص‌های شانون - واینر، سیمپسون، منهینیک و مارگالف) و ترسیب کربن درختی، پوشش علفی و خاک اندازه‌گیری شد.

یافته‌ها: ترسیب کربن درختان سرو نقره‌ای (۳۲/۳۲ تن در هکتار) و هم‌چنین خاک تحت آنها (۱۱/۱۵ تن در هکتار) از درختان عرعر (۱۷/۹۹ تن در هکتار) و خاک تحت آن‌ها (۷/۶ تن در هکتار) بیش‌تر بود. البته خاک تحت هر دو توده نسبت به منطقه شاهد (۵/۲۸ تن در هکتار) ترسیب کربن بیش‌تری داشت. براساس نتایج مشخص شد که پوشش علفی زیرآشکوب توده عرعر نسبت به توده سرو نقره‌ای کربن بیشتری را در خود ذخیره کرده است (۲۱/۳ تن در هکتار). هم‌چنین نتایج نشان داد که دو جنگل‌کاری مورد مطالعه از نظر تنوع زیستی زیرآشکوب اختلاف معنی‌داری باهم دارند (غنای منهینیک در دو توده عرعر و سرو نقره‌ای به ترتیب برابر با ۳/۱۷ و ۲/۴۴ بودند).

نتیجه‌گیری: جنگل‌کاری سرو نقره‌ای در مقایسه با عرعر در ترسیب کربن درختی و خاک موفق‌تر عمل کرده است. هم‌چنین غنای گونه‌های علفی زیرآشکوب توده عرعر بیشتر از سرو نقره‌ای است.

کلیدواژه‌ها
شاخص‌های تنوع زیستی؛
کربن آلی؛
جنگل‌کاری؛
ذی‌توده درختی

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