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Effect of Land Uses on Aboveground Biomass and Carbon Pools in Zagros Forests, Iran

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ABSTRACT

Aims Different types of land use have different effects on carbon stored in their pools and Co2 emissions. We compared carbon storage in different pools (tree, litter, and soil) across main land uses Mishkhas watershed in the northeast of Ilam province, Iran

Materials & Methods Oak forest (Quercus brantii Lindl.; Lu-F) and orchard (Juglans regia L; Lu-O) in 4 different ages were determined for estimation of carbon stocks in tree biomass, the litter, and 20 cm depth of soils in two land uses.

Findings The results showed that total carbon stocks in Lu-O ecosystem (68.75 Mg ha-1) was significantly higher than Lu-F (41.22 Mg ha-1). In general, soil at the two land uses was main carbon pool as estimated about 91% and (37.61 Mg ha-1) 82% (57.01Mg ha-1) of the total carbon stocks in Lu-F and Lu-O, respectively. The above ground biomass of trees was as second carbon pool and contained a lower contribution of total carbon stocks (roughly 6% and 15% in forest and orchard ecosystems). The least carbon storage i.e., about 2% of the total carbon stocks in Lu-F and Lu-O occurred in litter due to the grazing intensity.

Conclusion As a conclusion, our findings confirm that land use type can significantly effect on carbon stocks in different pools. Therefore, management strategies are needed to enhance the forest carbon sequestration in Mishkhas watershed of Ilam province.

Keywords Tree Biomass; Litter Carbon; Soil Organic Carbon Stock; Oak Forests; Juglans Regia

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Introduction

The rapid concentration of greenhouse gases (GHGs), especially carbon dioxide (CO_2), is considered the main cause of global warming and climate change [1]. Carbon exchanging between terrestrial ecological systems (in which carbon is retained in live biomass, decomposing organic matter, and soil) and the atmosphere play a key role in the global carbon cycle [2].

The Kyoto Protocol accounts a number of activities, including land use, land use change, and forestry as carbon source and sink in relation to a change in land cover and carbon stocks [3]. Land use that is defined as "exercising various agricultural and nonagricultural (development) practices," [4] contributes to approximately 25% of total global anthropogenic GHG emissions [5].

There is a growing interest to identify the role of different land use systems contribution in stabilizing the atmospheric CO_2 concentration, reducing the CO_2 emissions, and/or increasing the carbon sink [6].

Among land uses, forest land use, as an acceptable carbon sequestration vehicle [7], has specific advantages and it is so relevant due to large carbon pools and associated large GHGs fluxes generated by forest management and land use changes into and from forest [8] that does not require the development of any new science or technologies [7].

Carbon storage in forest ecosystems involves two main forest compartments, including biomass and soil [9]. Measurement of forest biomass provides an indication of C sequestration in trees, but additional information is required to estimate C stocks in litter, dead wood, and soil C pools [10]. However, the role of forests, as a carbon pool, is only ensured if the proportion of living biomass exceeds the loss of carbon due to dying biomass, forest fires, and harvest [11].

Land use change causes perturbation of the ecosystem and it can influence the carbon stocks and fluxes [9]. For example, soil organic carbon tends to be decreased when transforming grasslands, forest, or other native ecosystems to croplands [12]. The significant decrease (>70%) in soil organic carbon can be caused by reduction of annual organic matter input to soil as a result of deforestation [13]. However, its rate is controlled by certain effective agents, such as climatic factors and the intensity of cultivation [14]. Therefore, estimating carbon stocks is useful to evaluate the amount of C potentially emitted to the atmosphere due to land use changes [15]. However, the effect of human (overexploitation) on carbon storage in forested ecosystems has not been fully addressed and typically, carbon accounting studies do not present any values for arid or semi-arid regions [16].

One of the forested ecosystems in semi-arid regions is Zagros forests. In recent years, this forest has become more vulnerable due to climatic variability. As a result of decreasing precipitation and increasing temperature in this region, many trees have been lost in the western provinces of Iran [17]. Zagros forests cover an area of 5.2 million hectares of Iran [18] and represent the widest forest region of the country [19]. This region has the greatest impact on water and soil conservation, climate regulating, and socioeconomic balance [20]. Today, Zagros forest ecosystem is considered as degraded forests [21]. About 93% of Zagros forests are in coppice form [22] and non-woody products are usually of greater value than their direct productions. Ilam province encompasses all of these patterns but unfortunately, the scientific ignorance of the quantitative and qualitative dimensions of the various products and services led to degradation and land use change justifiable for other activities [23].

A challenging issue, neglected hitherto, is the assessment of potential for carbon storage in different land use types of the province. Therefore, estimation of the carbon stocks in Zagros forests is essential. Our objectives were to: (1) estimate the biomass and carbon storage in different pools (tree, litter, and soil) of oak forests (*Q. brantii* Lindl) and walnut (*Juglans regia*) orchard land uses in Ilam province, and (2) compare the effects of land use types on carbon sequestration. The hypothesis of this study were: (1) there is a significant difference between biomass carbon storage in forest and orchard land uses; and (2) the most important carbon pool in the studied land uses is living biomass, which included above and belowground carbon.

Materials and Methods

Study area: Zagros region extends along a climatic gradient in temperature and precipitation from northwest Iran toward the southeast [24]. Southern Zagros region has a longer dry season period and higher mean annual temperature compared to the northern area [17]. We focus on the Mishkhas watershed in Ilam province (46° 29' 12'' - 46° 38' 23'' E and 33° 30' 12'' - 33° 38' 46'' N), located in southern Zagros representing the varied land uses and high land use changes (Figure 1). According to data collected at the Mishkhas meteorological station over the period of 1986 to 2010, the mean annual rainfall is 533.6 mm with most rain in January to March. The climate is Mediterranean semi-humid and the corresponding mean air temperature is 16.8°C. The long dry season period (5 months) provides appropriate conditions for tree growth such as *J. regia.* because of its drought tolerance and ability to grow rapidly in poor habitats [25]. The structure of 90% of the inhabitants depend on animal husbandry, ranch, and, to some extent, agriculture. Thus, the fruit of the *J. regia* tree is an important source of income for farmers in this region. The study area has a total area of 13468 ha located at 1217-2630 m a.s.l. Two different land use types were selected in the study area including Lu-O (plantations of *J. regia*) with 1644 ha of the total area and Lu-F with 12386.02 ha (91.96%) covered by forests and natural vegetation (forests are dominated by Persian oak).

Over the past decades, the structure of the oak forests was high form, but over time, in order to preserve their survival, they were converted to coppice form [26]. See Table 1 details in supplementary selected land uses (source of Table 1 filed data from study area).

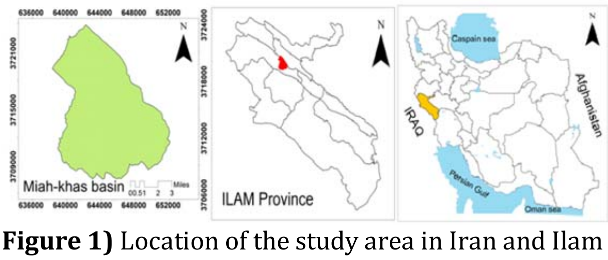

Figure 1) Location of the study area in Iran and Ilam Province

Field Sampling: There are several methods for estimating forest carbon stock, including sample plot inventory method, ecosystem modeling method, and remote sensing method [27]. Forest inventory data, which provide *in-situ* estimates carbon stock and fluxes across heterogeneous regions is the best approach for estimating forest biomass [28]. In this method, forest carbon stocks have been estimated by measuring the diameter (and/or height) of trees in the grid of sample plots, using allometric equations to estimate biomass [29]. According to the standard set for western coppice forests, we applied a systematic-random sampling with circular plots with of 1000 m^2 area in forest land use [30]. Based on the following sites inspection, 30 and 18 1000 m^2 sample plots for forest (Lu-F) and orchard (Lu-O) (Juglans stands were 5, 10, 25, and 45 years old) land uses were established in August 2017, respectively. To reduce the effects of environmental factors, all plots within each land use were adjacent to each other and were homogeneous in terms of altitude, topography, terrain, and soil [31]. The following allometric measurements from field sampling were recorded for each tree in the plots: height (H), diameter at breast height (DBH), height to the base of the crown (Hc), diameter of canopy in "length" (L), "width" (W), and tree density. The main characteristics of both land use type are presented in Table 1. Litter and soil sampling was limited to subplots of 1 m^2 square located in the center of each plot.

Biomass and carbon stock estimation: To estimate the trees biomass and carbon stocks in forest land use, biomass and carbon stock equations based on mean crown diameter as independent variable for coppice oak trees (Eqs. 1and 2) and 3 single stem trees in the plots number 11 (Eqs. 3and 4) developed by Iranmanesh *et al.* [32] were used.

$$AGB = 2.534 \times X^{2.383} \quad (1)$$

$$C_{AGB} = 1.275 \times X^{2.362} \quad (2)$$

$$AGB = 0.881 \times X^{3.228} \quad (3)$$

$$C_{AGB} = 0.425 \times X^{3.230} \quad (4)$$

, Where AGB and C_{AGB} (in kg) are tree biomass and carbon stock, respectively, and X (in m) is mean crown diameter.

Trees biomass and carbon stock were estimated in orchard land use and, then, basal area, volume of the trunk, and canopy volume of each tree were calculated. Following steps were done according to Hernandez's guideline [33]. The basal area of tree (Eqs. 5), the trunk volume (Eqs. 6), the crown volume (Eqs. 7):

$$Ab = \pi x\, r^2 \quad (5)$$

$$V_{Trunk} = Ab \times H \times Kc \quad (6)$$

$$V_{Crown} = (\pi \times Db^2)\ /12 \quad (7)$$

, Where Ab (in m^2) is basal area of tree, π=3.14, *r* is the radius of the tree at breast height (0.5

DBH), V_{Trunk} *(in m^3)* is the trunk volume, *H* (in m) is the tree height, *Kc* is a site dependent constant in standard cubing practice used in forest inventory (0.5463), V_{Crown} (in m^3) is the crown volume, and *Db* (in m) is the diameter of the crown canopy (to calculate Db, the average of the field measurements L and W is taken and used as the diameter of the crown: $Db = [L + W]/2$). In fact, most part of the volume is empty. Therefore, to estimate the actual crown volume, proportion of the volume is occupied by branches and foliage (estimated by a careful visual appreciation of the canopy structure) used to discount the air space in the crown volume [33]. We computed tree biomass (Eqs. 10) by adding the trunk biomass (from Eqs. 8) to the crown biomass (from Eqs. 9):

$$AGB_{Trunk}=V_{Trunk}\times WD_{Trunk}\times 1000 \quad (8)$$

$$AGB_{Crown}=V_{Crown}\times WD_{Crown} \quad (9)$$

$$AGB_{tree}=AGB_{Trunk}+AGB_{Crown} \quad (10)$$

, Where AGB_{Trunk} and AGB_{Crown} (in kg) were trunk and crown biomass, respectively, and WD_{Trunk} *and* WD_{Crown} (in $gr.cm^{-3}$) were wood density. WD was estimated for *J. regia* to better prediction of above ground biomass according to the Eqs. 11 [34]:

$$WD=wd / Vf \quad (11)$$

, Where *Wd* is the oven-dry weight of wood sample and *Vf* is the weight of water displaced by fresh wood sample. Then, for the carbon contained in the aboveground biomass (AGB) of the *J. regia* trees, the following equation was applied (Eqs. 12):

$$C_{AGBtree}=AGB_{tree}\times C \quad (12)$$

, Where $C_{AGBtree}$ (in Kg) is carbon stored in the AGB and C is the organic carbon.

The belowground biomass (BGB) was estimated based on a non-destructive method suggested by MacDicken [35]. In this estimation, the ratio of belowground to AGB in forests is considered about 0.2, depending on species. According to Askari *et al.* [36], ratio of 0.80 was adopted for Persian oak due to decreasing soil moisture content that makes higher ratio [37]. We cautiously considered the BGB content to be 20% of the total AGB. This ratio is a reasonable estimate from the literature [33]. Additionally, the coefficient of 0.5 for the conversion biomass to C [38] was applied to obtain the belowground carbon.

To estimate organic carbon storage in litter, at the first, the fresh litter samples were dried in the oven for 24 hours at 70°C and, then, the weight was measured. Next, the samples were burnt at 400-450°C for 4 hours in electrical furnace. After cooling, the crucibles with ash were weighed. We applied the relationships 13 and 14 for calculated percentage of organic carbon in litter [39]:

$$Ash\%=(w_3-w_1) / (w_2-w_1)\times 100 \quad (13)$$

$$C\%=(100-Ash\ \%)\times 0.58 \quad (14)$$

, Where *C* is the organic carbon, *W*1 is the weight of crucible, *W*2 is the weight of oven dried grind samples + crucibles, and *W*3 is the weight of ash + crucibles.

Soil sampling was taken out from the upper 20 cm, where changes in soil C and N were expected to occur [40]. Soil samples were dried in open air covered area and, then, grounded and passed through 2 mm sieve (mesh 20) to remove stones and gravels. For forest and orchard land uses, 10 and 15 soil samples were prepared and transferred to the laboratory for the further analyses, respectively. The percentage of stones in the soil samples was calculated. Soil texture was determined according to United States Department of Agriculture (USDA) standards [41]. The soil samples pH was measured, using a mixture of 1:2.5 deionized water and soil by a pH meter. Total nitrogen was measured, using a Kjeldhal technique [42]. The bulk density was determined volumetrically (g cm^{-3}) by using the clod method [43]. Organic matter and organic carbon contents were assessed by the acid oxidation method [44]. The soil carbon stock (Cs, Mg ha^{-1}) was measured, using the relationship 15 [45]:

$$C_S=OC\%\times Bd\times E\times(1-R_f) \quad (15)$$

, Where *OC%* is the soil organic C content (%), *Bd is* the bulk density *(g cm^{-3}), E* is depth of the sampled layer (cm), and R_f is percentage of rock fragments (relative to the mass of soil).

Data analysis: The data were checked for normality and homogeneity of variance, using Kolmogorov-Smirnov test and the Levene's test, respectively. Statistical analyses were performed, using SPSS 16.0 for Windows (SPSS Inc., USA). An "independent samples t-test" ($\alpha=0.05$) was applied to determine the differences among mean values in the land use types.

Findings and Discussion

Structural characteristics: The structural characteristics and the values of measured parameters of the sampled sites are reported in Table. 1. Stands structure (e.g., stand density and mean diameter of crown) significantly differed between Lu-F and Lu-O. In general, stand density (in ha^{-1}) was 230 and 100 in 5 and 45 years old stands, respectively, and mean diameter of crown was higher in Lu-O than Lu-F. This heterogeneity of stands structure among sites highlights the importance of stand structure as a key factor to growth, function, and disturbance regimes of forests [46]. Tree height and DBH values did not have any significant difference between two land uses. ($p>0.05$; Table 1).

Table 1) Summary statistics of the dendrometric characteristics and soil physio-chemical properties for each parameter in two investigated land uses; Lu-F (n=30), Lu-O (n=18)

Characteristics	Range	Mean	Std. error
Site			
Altitude (m a.s.l.)			
Lu-F	1681-1837	1759	8.73
Lu-O	1444-1840	1631	51.37
Slope (%)			
Lu-F	19-23	21.8	0.75
Lu-O	13-21	16.5	1.12
Stand			
Height (m)			
Lu-F	2-7.5	5.03^{a}	0.1
Lu-O	2-11	5.91^{a}	0.54
DBH (cm)			
Lu-F	8-60	20.18^{a}	0.69
Lu-O	4-55	20.87^{a}	3
DC (m)			
Lu-F	1-5.5	3.08^{b}	3.52
Lu-O	2-8.75	5.03^{a}	0.41
Trees (n ha^{-1})			
Lu-F	60-150	102.67^{b}	142.78^{a}
Lu-O	100-230	142.78^{a}	8.23
Soil			
Bd (g cm^{-3})			
Lu-F	0.73-1.01	0.88^{a}	0.03
Lu-O	0.87-1.8	1.1^{b}	0.07
Rf (%)			
Lu-F	13.3-40	25.30	2.89
Lu-O	24-42.85	31.14	1.52
Clay (%)			
Lu-F	21.5-38	28.3^{a}	1.62
Lu-O	22-31	27.53^{a}	0.84
Silt (%)			
Lu-F	19-28	24.75^{a}	1.16
Lu-O	18.5-25	22.46^{a}	0.52
Sand (%)			
Lu-F	42-54	46.95^{b}	1.25
Lu-O	46-55	50^{a}	0.73
OC (%)			
Lu-F	0.71-5.39	2.82^{a}	0.5
Lu-O	2.14-6.03	3.82^{a}	0.3

(DBH): diameter at breast height; (Height): tree height; (DC): crown diameter. Soil texture: sandy clay loam. Soil depth= 20 (cm). (Bd): bulk density; (Rf): Rock fragments; (OC): organic carbon. Data show the mean ± SE. Different letters in rows indicate significant differences between land uses after t test ($p<0.05$)

Biomass and carbon storage in trees: The AGB ranged from 2.08-8.8 Mg ha^{-1} for Lu-F to 0.978-48.372 Mg ha^{-1} for Lu-O (Table 2) with significant difference ($p<0.05$) between sites. These findings were inconsistent with previous report [47] that investigated estimating the amount of carbon storage in biomass of different land uses in northern Zagros forest. They reported that total biomass was higher in forest land use (12.85 mg ha^{-1}) than orchard (5.38 mg ha^{-1}). Tree biomass variation may differ by site conditions, altitude, forest type, stand age, species composition, size class of trees, rainfall pattern, and edaphic factors [48-51]. Lu-O showed significantly ($p<0.05$) higher BGB compared to Lu-F, which could be due to high AGB value of Lu-O site than Lu-F. The more AGB, the more BGB.

Table 2) Biomass and carbon stocks (Mg ha^{-1}) in trees of each land use

Component	Range	Mean	Std. Error	T-value	p-value
AGB					
Lu-F	2.08-8.81	4.41^{b}	0.26	-2.941	0.009
Lu-O	0.98-49.12	16.08^{a}	3.9		
BGB					
Lu-F	0.42-1.76	0.88^{b}	0.05	-2.943	0.009
Lu-O	0.2-9.82	3.21^{a}	0.79		
TTB					
Lu-F	2.5-10.57	5.29^{b}	0.32	-2.942	0.009
Lu-O	1.18-58.94	19.3^{a}	4.7		
C_{AGB}					
Lu-F	1.02-4.28	2.16^{b}	0.02	-3.081	0.007
Lu-O	0.55-27.38	8.97^{a}	0.39		
C_{BGB}					
Lu-F	0.21-0.88	0.44^{b}	0.13	-2.94	0.009
Lu-O	0.1-4.9	1.6^{a}	2.2		
C_{TTB}					
Lu-F	1.23-5.16	2.6^{b}	0.15	-3.06	0.007
Lu-O	0.65-32.29	10.58^{a}	2.6		

TTB: Total tree biomass. C_{TTB}: Carbon stock of total tree biomass. Data show the mean ± SE. Means followed by the same letter in row are not significantly different after t test ($p<0.05$)

In forest ecosystem, the mean AGB was lower than those reported for coppice forests in Ilam province [52]. Recent study was carried out in stands with higher density and mean diameter crown. Whereas, trees growth in low-density stands usually contain relatively more biomass in branches and foliage than in high-density stands [53]. Besides, in *Q. persica* tree, tree crown contains 66.7% of AGB [32]. Thus, differences in the structural characteristics caused the variation in the AGB content between studies.

The nearby villages to the studied forest sites, grazing by domesticated livestock, cutting trees for fuelwood and land use converting from forest to other usage (*e.g.*, agriculture and pasture land) led to high degradation. Under such degradation, the obtained results were even lower than the results reported in the same forest ecosystems in central and south parts of Zagros [54]. In orchard ecosystem, the mean estimation of AGB (16.08 mg ha^{-1}) was close to the values reported for Juglans trees (14.59 mg ha^{-1}) of Kedarnath Wildlife Sancturay [55]. Value of 124.6 Mg ha^{-1} were recorded by Dar and Sundarapandian [56] for AGB of *J. regia* at managed plantations in Kashmir Himalaya that is comparatively higher than value obtained in the present study. This might be due to a difference in stand structure (*i.e.*, tree height, diameter at breast height, and tree density). The sampled land uses were different in carbon pool of AGB. The aboveground carbon (C_{AGB}) was higher in the Lu-O (8.97 Mg ha^{-1}) than in the Lu-F (2.16 Mg ha^{-1}). *J. regia* plantation increased the biomass carbon stock by 8 mg ha^{-1} in comparison to natural forest. This is quite logical due to the higher biomass.

Hoover *et al*. [57] believed that the higher level of carbon storage per unit area was due to the larger biomass component. The results of a study conducted by Baishya *et al*. [58] in comparison of the carbon storage potential of natural semi-evergreen forest and Sal (*Shorea robusta*) plantation forest in the humid tropical region of northeast India are in good agreement with our findings. Their results suggest that although both forests had the potential for carbon sequestration, but the Sal plantation had an edge over the natural forest because of better silvicultural practices [58].

According to Proietti *et al.* [59], oak plantation had the lower net CO_2 sequestration compared to the walnut plantation. This result was justified from the biological point of view; this situation could change at later stage, since trees like oak can maintain high CO_2 sequestration levels after the culmination of the walnut growth rate [59]. Therefore, we infer that in our conditions, lower capacity of oak forest for carbon storage can be relative to threat from anthropogenic pressures in combination with climatic and other ecological factors [54], which caused degradation of this forest.

C_{AGB} value under Lu-F (2.16 Mg ha^{-1}) was interestingly lower than those found for stands of *Q. persica* in other places in Zagros forests such as values of 26.85 and 21.08 Mg ha^{-1} in central and south Zagros, respectively, reported by Askari *et al*. [54] and 4.65 Mg ha^{-1} estimated by Alinejadi *et al*. [60].

A research assessing carbon storage revealed that the final result often depends on initial stand conditions [57]. Moreover, genetic features, site productivity, and climate and unexpected factors can effect on oak stands in western Iran [60]. In west central Himalayas, Garkoti [61] reported mean tree biomass carbon 5.4 Mg ha^{-1} for *J. regia* stand plantation. Bhat *et al*. [55] estimated 9.74 mg ha^{-1} for a *J. regia* stand plantation in Kedarnath and 35.45 Mg ha^{-1} was recorded by Abdipour *et al.* [62] for a walnut orchard in Semnan province, Iran. It is difficult to compare the C_{AGB} sequestration estimation of the present study with other works due to (i) different methods used for biomass estimation (direct estimation of biomass or using the allometric and regression equations) and (ii) the fraction of C_{AGB} used to convert biomass to C_{AGB} stocks that varied in different studies [50].

Carbon storage in the litter, soil, and total carbon stock of each ecosystem: The soil of two land uses had similar texture with differences in some properties (Table 1). Our result indicated that the sand (%) and soil bulk density at depth of 0-20 cm was significantly higher in Lu-O compared to the Lu-F (Table 1). Soil carbon stocks (C_{soil}) were 37.61 Mg ha^{-1} and 57.01 Mg ha^{-1} at depth of 20 cm in the Lu-F and Lu-O sites, respectively (Table 3) with significant difference ($p<0.05$) between sites.

The result demonstrated that tree species and land use changes can significantly effect on soil carbon stocks [40]. That is in line with the results of the present study. Furthermore, the C_{Soil} is strongly controlled by land use [63]. In our study, the differences between the means of the estimated C_{Soil} for both land use types can be explained by the facts that orchard land use had higher stand density and biomass values compared to forest land use. Some factors were attributed in this study as sensitivity carbon stock on vegetation biomass [64], stand density and volume per hectare [16], and differences among soil carbon stocks in land uses. In contrast, the soil carbon accumulation and stocks is intensively deponent on some factors, such as vegetation types [65], which control the amount, quality and distribution of litter fall, and associated microbial communities, which decompose these inputs [66], land use, and management practices [67]. It is important to consider that orchard land use soil contains higher sand%, and higher stored organic carbon [68].

Table 3) Carbon stocks (Mg ha^{-1}) in the Soil (C_{Soil}), Litter (C_{Litter}), and total carbon stock (C_{Total}) of each ecosystem

Component	Range	Mean	Std. Error	T-value	p-value
C_{Soil}					
Lu-F	7.98-64.17	37.61 ^{b}	6.62	-2.3	0.03
Lu-O	32.52-101.95	57.01 ^{a}	5.27		
C_{Litter}					
Lu-F	0.01-2.12	1.01 ^{a}	0.17	-1.05	0.3
Lu-O	0.57-1.76	1.16 ^{a}	0.08		
C_{Total}					
Lu-F	9.22-71.45	41.25 ^{b}	6.64	-2.6	0.01
Lu-O	33.74-136	68.85 ^{a}	7.89		

Data show the mean ± SE. means followed by the same letter are not significantly different after T test ($p<0.05$)

The average soil carbon stocks content (37.61 t ha^{-1}) in Lu-F was lower than previous report for *Quercus – Zelkova* natural stands (121.43 t ha^{-1}) from north of Iran [69] and intact (219 t ha^{-1}), protected (208 t ha^{-1}), and exploited (194 t ha^{-1}) oak forests from northern Zagros [47]. Additionally, the average soil carbon stock content in Lu-O was considerably lower than results in non-Zagros region [62]. This could be due to differences in soil sampling depth [51] as we sampled from 0-20 cm compared with others from 0-50 and 0-100 cm.

In our study, no significant difference was observed in the litter carbon storage (C_{Litter}) between two sites (Table 3). The analysis revealed no significant variations in C_{Litter} between Lu-F and Lu-o. The mean C_{Litter} under our conditions are close to 1.07, 1.37, and 1.58 Mg ha^{-1} reported for mixed, deciduous, and evergreen forests, respectively, in Kolli forests [70]. Litter carbon values in the studied sites are comparatively lower than those reported by Varamesh *et al.* [71] for other species; however, similar sampling methods were used. The human overpressure on the area (e.g., pasture with domesticated livestock) may explain why there was no association between studies. Indeed, C_{Litter} is highly susceptible to human disturbances [48].

In Mishkhas watershed, total carbon stock (C_{Total}, i.e tree biomass, litter, and the soil at 20 cm depth) was higher under Lu-O (68.75 Mg ha^{-1}) than under Lu-F (41.22 Mg ha^{-1}). In all the two land uses, the most important carbon pool of these ecosystems were soil with 37.61 and 57.01 Mg ha^{-1} *i.e.*, about 91% and 82% of the total carbon stocks in Lu-F and Lu-o, respectively (Figure 2). Soils store more C (2500 billion tons) than the atmosphere (780 billion tons) and vegetation (560 billion tons) that combined together make them the largest terrestrial C store [4].

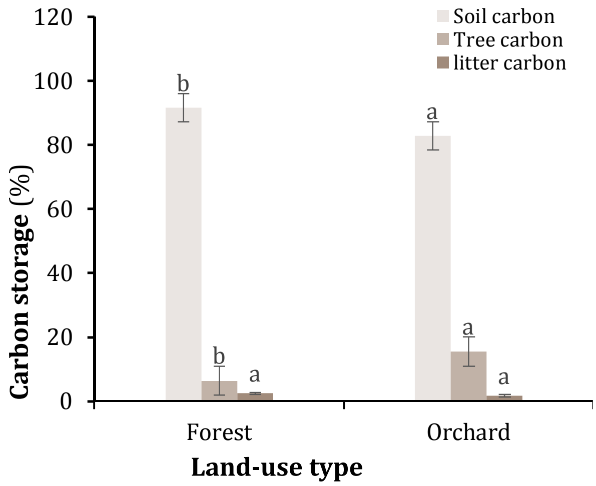

Figure 2) Carbon stocks estimated the components (tree, litter, and soil) of the both land uses

Eslamdoust and Sohrabi [72] estimated the soil carbon storage (largest carbon pool in the ecosystem) 78–87% of ecosystem carbon storage in the South Caspian Sea, coinciding (to some extent) with our findings. The second pool of carbon was the carbon in trees biomass pool, which estimated roughly 6% for Lu-F and 15% for Lu-O and, finally, the contribution of the litter to carbon withhold was about 2% for Lu- f and Lu-O (Figure 2).

Results were also compared with previous findings by Varamesh *et al.* [71], who showed that the AGB in *Cupressus arizonica* stands is the major storage compartment of ecosystem. Difference tree species were used in different studies. Coniferous forests had a higher live biomass and litter Carbon storage, whereas broadleaf forests had considerable soil carbon sequestration potential [73]. Conversely, Sariyildiz *et al.* [40] found that mineral soil in broadleaf stands contained less carbon than mineral soil in conifer stands. It should be noted that carbon values in the present study was considerably lower than the values reported from different land uses of northern Zagros [47]. We believed that widespread degradations are the main reasons for low oak tree stand density that are mostly appeared in only coppice form with low crown diameter (about 6 m). It is well known that stand density affect tree crown morphology, which in turn influences on the carbon allocation among stems, foliage, and branches [74].

Noticeably, the lower tree density together with the limited canopy extension led to tremendous loss of soil carbon, underlining the strong relationship between stand biomass and soil carbon [16]. However, the results of this study revealed that the enhancement of the biomass and carbon stocks should be considered by watershed managers. Furthermore, estimation carbon stocks in other pools (such as woody debris, understory vegetation, and soil at different depth) are needed to exposure the total carbon stocks of the region.

Conclusion

In this study, we compared two land uses in terms of biomass and carbon storage in different pools (tree, litter, and soil) in southern Zagros. Our findings showed significant changes in biomass and carbon storage between land uses, while orchard land use had the highest biomass and carbon storage. Soils in Mishkhas watershed land uses were the main carbon pool in forest and orchard land uses. These stocks are lower than earlier studies. The evidences revealed that threat from historical human pressures with climate changes and other ecological factors across the region lead to widespread degradation, followed by loss of organic carbon from the soil organic carbon stocks and other carbon pools. However, estimation carbon stocks in other pools (such as woody debris, understory vegetation, and soil at different depth) are needed to exposure the total carbon stocks of the region.

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