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An introduction to the distribution of carbon stocks in temperate broadleaf forests of northern Iran

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Abstract: Northern forests of Iran are among the most important plant communities in Iran due to their dynamic and diverse vegetation composition and fertile soils. There is little information about carbon stocks of these forests. In the present study, above- and belowground carbon stocks of trees, litter, herbs and soil organic carbon stock at three selected sites of these forests were calculated using random plots and non-destructive sampling. The FAO method was used for carbon estimation of trees and Walkley-Black method was used for soil carbon stock and carbon coefficient was estimated directly. The results showed that both the tree carbon stocks and soil carbon stocks increased from east to west with increasing altitude, showing significant differences. The results also indicate that these forests have a high carbon sequestration potential as a green belt across the northern slopes of the Alborz Mountains, when the contribution of the aboveground section was greater than that of the belowground section (soil and roots) at all sites.

Keywords: carbon; temperate forests; soil carbon; litter; herb; trees

Increasing greenhouse gases have been among the causes of climate change in recent years and the most effective of these gases is carbon dioxide (Houghton, Skole 1990; Li, Tang 2006; Pachauri et al. 2014; Pragasan 2014). Today, there is a great deal of focus on forest ecosystems to prevent the increase of these gases and to control global climate change (Zhu et al. 2010). Forest ecosystems as absorbers of CO_2 store large amounts of atmospheric carbon through photosynthesis in soil and vegetation (Qureshi et al. 2012; Chen et al. 2019). Much of the carbon is stored in various pools in a forest ecosystem in living above- and belowground biomass, including standing trees, branches, leaves and roots, litter, dead wood debris, soil organic carbon and forest products while carbon has been stored for decades and centuries (Malhi et al. 2002). Forest carbon stocks are the primary output of many complex processes at different spatial and temporal scales (Alvarez-Davila et al. 2017). On a global scale, there are various achievements in studies of this kind. Therefore, there is no certainty about the spatial distribution of carbon stocks in forest ecosystems. This can be due to human activity and environmental heterogeneity. Microclimate and topography also influence the spatial distribution of carbon stocks and cause changes in it (Jia, Akiyama 2005). Forest soils also play a key role in the global carbon budget and greenhouse effects by interacting with vegetation (Murillo 2008). According to this, increasing amounts of carbon captured and stored

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by forests (vegetation and soil) have always been considered as an option in climate change mitigation, sustainability of the carbon cycle in the atmosphere and soil, and prevention of global warming (Zhu et al. 2010; Gairola et al. 2011; Ekoungoulou et al. 2014; Yu et al. 2014; Motlagh et al. 2018).

According to the FAO report, in 2015 the area of forest ecosystems in the world was declining more than ever before (FAO 2015). This is especially true in developing countries which are experiencing an increasing trend of deforestation and destruction. Accurate measurement of carbon stored in forest ecosystems is one of the most fundamental issues under consideration by ecologists, which is essential for the assessment, monitoring and management of carbon emissions worldwide and for controlling the current crisis (Zhu et al. 2010). To do this, we need to have an accurate estimate of the amount of carbon trapped in the forests. Ecologists have estimated the amount of carbon in the forest ecosystem and have realized what carbon stocks have existed in the forest ecosystem so far and what removal or preservation of this stock can lead to an increase or decrease in CO_2 emissions (Kumar, Mutanga 2017).

Hyrcanian forests in the north of Iran are the remnant broadleaved forests of the Tertiary era. They are highly regarded as a valuable natural heritage and remarkable forest ecosystem with diverse and unique species and fertile soil at a regional and global level (Marvie-Mohadjer 2012; Sagheb-Talebi et al. 2014). These forests belong to the richest and most exquisite vegetation communities in Iran and are mainly dense due to their suitable ecological conditions. They have a sensitive situation for study and protection (Mohammadi et al. 2015). The dramatic decline in the level of these forests (both quantitatively and qualitatively) has been evident in Iran in recent years. However, species composition, distribution, biodiversity, growth patterns and community structure have been studied in these forests in recent years (Bonyad et al. 2012; Ahmadi et al. 2013; Bayat et al. 2014; Mohammadi et al. 2015), but investigations of carbon stocks in these forests are still poor.

Unfortunately, there is no accurate and comprehensive information on carbon stocks in the Hyrcanian forests in northern Iran, which can be used to determine the true contribution of these forests in the region and their response to climate change in recent decades (Ghanbari Motlagh et al. 2019). In order to prevent further destruction of these forests careful planning and correct actions are necessary. Therefore, in this study, carbon stocks were investigated in two sections, aboveground and belowground, and at three sites of the presence of these forests based on a non-destructive method. In order to calculate the carbon stocks in the tree layer the parameters such as diameter at breast height, height, crown dimensions and wood density, which are the best applied variables in this regard, can be easily measured (Ekoungoulou et al. 2014). Direct sampling was also used to estimate carbon content. Also, although most researchers consider only the stem section for tree carbon calculations, in the present study for calculating the biomass of the tree layer, the contribution of the crown was calculated in addition to the stem biomass in the tree layer calculations.

MATERIAL AND METHODS

Study area. Geographically, Hyrcanian forests in northern Iran are a part of the Hyrcanian vegetation zone (Marvie-Mohadjer 2012). The present area of these forests is about 1.8 million hectares (Hosseini 2010). They look like broadleaf forests in central Europe, northern Turkey and in the Caucasus. However, the registration of 80 tree species in these forests has included them among the richest forests in the species (Jafari et al. 2013; Sagheb-Talebi et al. 2014). The species such as *Fagus orientalis Lipsky*, *Parrotia persica* C.A.M., *Carpinus betulus*, *Quercus castaneifolia*, *Pterocarya fraxinifolia*, *Gleditschia caspica*, *Alnus subcordata*, *Cerasus avium*, *Diospyrus lotus*, *Acer* sp., *Ulmus glabra*, *Sorbus torminalis*, *Tilia begonifolia* and *Populus caspica*, etc. are some of the species found in these forests that generally have uneven-aged structure (Marvie-Mohadjer 2012; Mohammadi et al. 2015)

These forests extend over the Alborz Mountains from Astara in the westernmost region to Golgi Daghi in the easternmost region and they are 800 km long and 20 to 70 km wide (Sagheb-Talebi et al. 2014; Ghanbari Motlagh et al. 2019). The climate of the north of Iran is a semi-Mediterranean climate and the weather is temperate and humid. The mean temperature is 15–18 °C. The average annual rainfall is 600 to about 2,000 mm per year and decreases from west to east. The length of the dry period increases

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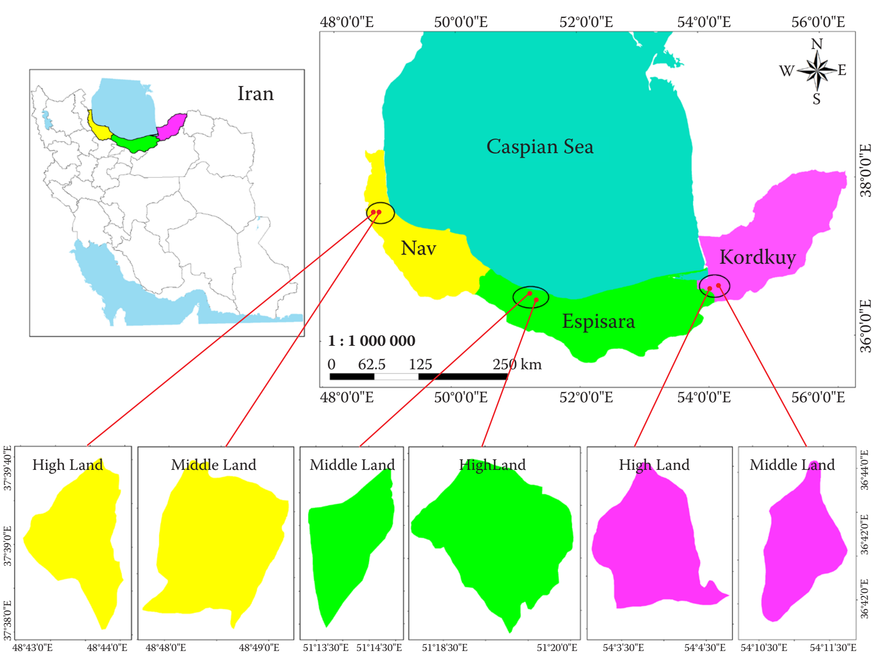

Figure 1. Location map of the study sites in Iran

from west to east (Ghanbari Motlagh et al. 2019). The soils of these forests are of the brown forest, Rendzina and Ranker types. The parent rock in most of the regions is from the Jurassic and Cretaceous periods (Marvie-Mohadjer 2012).

This study was carried out at three sites within the three forestry plans of Nav, Espisara and Kordkuy, respectively, as representatives in the west, centre and east of temperate forests of northern Iran (Figure 1). 140 sample plots of 900 m^2 in size were randomly established at two altitudes (middle land and high land) at three sites (Table 1). The characteristics of the study sites are presented in Table 1. The climate of the region is in the range of very humid, humid, semi-humid to Mediterranean based on the Domarton method (Table 1).

Study method. In this study forest carbon stocks were studied in two parts of vegetation; aboveground carbon (AGC) which generally includes carbon stock in live standing trees, herbs, litter and belowground carbon (BGC) contained in roots and soil carbon.

The measurement method used in this study, which is a non-destructive method, was to generate the most accurate estimation with minimum damage and cost. In calculating the carbon content of whole trees, their biomass should be obtained first. Aboveground tree biomass is a function of

Table 1. Characteristics of the three study sites

Site	Nav		Espisara		Kordkuy	
	(High land)	(Middle land)	(High land)	(Middle land)	(High land)	(Middle land)
Altitude (m)	1 500–1 850	400–800	1 500–1 850	400–800	1 500–1 850	400–800
Soil texture	loam, clay-loam	sandy-loam	clay, clay-loam	loam, clay-loam	silt-loam	clay-loam, silt-loam
Stand type	beech	mixed broadleaf	mixed broadleaf	beech	mixed broadleaf	beech
Number per ha	196	189	126	100	108	102
A_b ($m^2 \cdot ha^{-1}$)	41.1	34.1	22.9	15.6	25.6	15.5
$\overline{DBH}$ (cm)	45.2	42.0	41.2	38.2	44.4	36.9
$\overline{H}$(m)	20.2	19.0	21.7	21.3	26.8	18.6

Beech – pure stand of beech (Fagetum) with more than 90% of *Fagus orientalis* Lipsky and other broadleaf species; mixed broadleaf – a mixed stand of broadleaf species (*Carpinus betulus*, *Acer* sp., *Sorbus torminalis*, *Cerasus avium*, *Fraxinus excelsior*, *Alnus subcordata*, *Diospyrus lotus*, *Ulmus glabra*, *Tilia begonifolia*, *Pterocarya fraxinifolia*, *Pterocarya fraxinifolia* C.A.M., *Fraxinus excelsior*, *Quercus castaneifolia*)

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the tree volume – volume of the crown and stem (derived from diameter and height), form of tree, wood specific gravity, and it is commonly used throughout the world for forest ecological surveys and studies (Mani, Parthasarathy 2007). For this purpose, diameter at breast height (DBH) of all trees with diameter greater than 7.5 cm, height (*H*) and canopy dimensions were measured in all samples.

The FAO method was applied to calculate aboveground tree biomass (Ponce-Hernandez et al. 2004). Accordingly, stem volume (V_s) and canopy volume (V_c) based on formulas (1), (2) and (3) and with basal area parameters (A_b) and total tree height (H), tree form factor (Kc), average of the crown diameter variables ($\bar{D}$) and correction factor (F_c) were calculated. The average (K_c) was chosen to be 0.5 in this study (Zobeiry 2000). ($\bar{D}$) is the average of the crown diameter variables obtained from Equation (4) where (*L*) is the crown length and (*W*) the crown width. Crown width was measured with a measuring tape in two directions perpendicular to the north-south and east-west. Crown length was also obtained by minus the two variables of tree height and crown base height (Naghipurborg et al. 2013). Equation (3) was used to calculate the canopy volume of each tree (V_c). On this basis, the parabolic shape of beech as well as other broadleaves in the stands was selected, when observations also confirmed the compatibility of the parabolic shape for this purpose (Nemiranian 2010). (F_c) is the correction factor calculated by the optical method and expressed as a percentage of the total volume of the crown (Nemiranian 2010; Zobeiry 2000).

$$A_b = (0.785) \times DBH^2 \quad (1)$$

$$V_s = A_b \times H \times K_c \quad (2)$$

$$V_c = (\pi \times \bar{D}^2/12) \times F_c \quad (3)$$

$$\bar{D} = (L + W)/2 \quad (4)$$

After summing the total volume values of stem and tree crown (*V*), the wood dry density (*WD*) was calculated using the dry weight density method (Ullah, Alamin 2012). Next, the aboveground biomass of tree (*B*) (crown, stem) was produced from Equation (5):

$$B = V \times 1\,000 \times WD \quad (5)$$

The root biomass of trees was estimated based on FAO guidelines for broadleaf species equivalent to 0.3 aboveground biomass of trees. As a result of these calculations, the estimated biomass of the plots was acquired.

Herbaceous and litter data were collected from 1 and 0.25 m^2 microplots, respectively, within the main plots, simultaneously with field surveys (Ponce-Hernandez et al. 2004). In order to collect the herbaceous data within each main plot, a 1 × 1 m^2 microplot was placed in the centre of the main plot and another 4 microplots equally in the 4 corners of the main plot. The same method was applied to the microplots of 0.5 × 0.5 m^2 in size for litterfall data (Salunkhe et al. 2014). Afterwards, all the herbs and the collected litter were weighed and transferred in plastic bags to the laboratory. Samples were placed in an oven at 65° C for 48 hours to determine dry weight (Zhu et al. 2010). In this study, carbon concentration or carbon factor was calculated directly by a combustion method with electric furnace to determine the actual carbon content of biomass of trees and herb and litter samples (Vahedi et al. 2016). In the laboratory, after grinding and preparing the samples, equal quantities of all the herbaceous, litter and fragmented samples of the trees were weighed by placing them in the oven after drying. The samples were placed in crucible bushes and put in an electric furnace at 400 °C. After the crucible bushes had dried and the samples inside them were ash, they were re-weighed. Then, by converting the organic matter to organic carbon, having the initial weight and the weight of the ash, finally the carbon coefficient was calculated for each sample (Ullah and Al-Amin 2012). In this study, basal area was calculated in terms of m^2, stem volume and crown volume in m^3, biomass and total carbon content of trees in tons per ha.

To determine the soil carbon stock, after removing the litter layer, composite soil samples were taken from the 4 corners of 5 × 5 m microplates created within the main plots. They were collected from a depth of 0-30 cm and transported to the laboratory. Bulk density (Bd) using the Blake and Hartage (1986) method in grams per cubic centimetre (Blake and Hartage 1986) and soil organic carbon (*OC*%) were obtained by the Walkley-Black method (Walkley and Black 1934). Using Equation (6), the amount of stored organic carbon (*Cs*) in the soil sampled depth (*E*) was calculated in tons per ha (Vahedi et al. 2016).

$$Cs = Bd \times E \times OC\ (\%) \quad (6)$$

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Table 2. Carbon values of different forest sections (t·ha^{-1}) at study sites

Site	Nav		Espisara		Kordkuy	
	(High land)	(Middle land)	(High land)	(Middle land)	(High land)	(Middle land)
Crown and stem carbon stock	303.9 ± 123.2	249.6 ± 94.2	222.5 ± 74.7	126.1 ± 61.8	153.6 ± 55.1	107.9 ± 55.4
Root carbon stock	91.2 ± 36.9	74.9 ± 28.3	66.7 ± 22.4	37.8 ± 18.5	46.1 ± 16.5	32.4 ± 16.6
Herb carbon stock	1.4 ± 30.0	7.7 ± 13.9	0.3 ± 1.7	6.0 ± 2.9	5.1 ± 11.0	59.6 ± 66.6
Soil carbon stock	90.2 ± 14.7	57.3 ± 13.2	76.3 ± 8.9	56.8 ± 17.3	70.9 ± 17.7	54.2 ± 28.2
Litterfall carbon stock	21.6 ± 14.9	13.4 ± 15.9	17.9 ± 12.2	14.4 ± 9.1	7.0 ± 6.3	16.2 ± 12.8
Total carbon stock	508.3 ± 173.9	402.9 ± 135.7	383.7 ± 106.1	241.1 ± 97.3	282.8 ± 89.3	270.2 ± 100.3

In order to analyze and compare the data, carbon data of trees, herbs, litter and soil carbon data were entered into SPSS (IBM, Armonk, New York, USA). ANOVA analysis and Duncan's test were used to compare all data between sites. The *t*-test was used to compare the carbon values at the two altitudes. Mann-Whitney *U* tests and Kruskal-Wallis *H* nonparametric analysis of variance were employed to compare the herbaceous carbon stock for comparing the altitudes and general comparisons between sites, respectively.

RESULTS

Estimated carbon stocks in different sections of study sites are presented in Table 2. Analysis of variance of the obtained data showed that the difference between tree carbon stock in the aboveground biomass (stem, crown) and root carbon between the three sites in both high and middle land was significant and showed a significant decrease from west to east in these forests. Comparison of the means between soil carbon stocks in the three study sites showed that the differences were significant and had a decreasing trend from west to east but no differences were observed between middle lands at the three sites. In the case of carbon in the litter section, results were similar to soil carbon ($P \leq 0.05$) (Table 3) (Figure 2 and 3). The results of the Kruskal-Wallis *H* analysis for the three sites on herbs at both altitudes also illustrated significant differences ($P \leq 0.05$) (Figure 2 and 3) (Table 4).

The results of this study indicated that at all three sites there was an increasing trend in the values of stem and crown carbon, root carbon, soil carbon, and a decreasing trend for herbaceous carbon when moving to higher altitudes. The differences

Table 4. Kruskal-Wallis *H* test results for herb carbon stocks at the study sites

Carbon stock source		Chi-square	df	Sig.
Herb	(High land)	15.6	2	0.000**
	(Middle land)	7.0	2	0.030*

**significant at 99%, *significant at 95%

Table 3. Results of the analysis of variance of carbon stock in different sections at the study sites

Carbon stock source		Sum of Squares	df	Mean Square	*F*	Sig.
Tree	Aboveground (High land)	218 933.6	2	109 461.8	13.1	0.000**
	Aboveground (Middle land)	187 170.1	2	93 585.0	17.6	0.000**
	Belowground (High land)	19 703.1	2	9 851.6	94.9	0.000**
	Belowground (Middle land)	16 845.3	2	8 422.6	11.6	0.000**
Litterfall	(High land)	2 583.1	2	1 291.5	8.7	0.000**
	(Middle land)	69.9	2	34.9	0.2	0.806ns
Soil	(High land)	5 019.7	2	2 509.9	13.5	0.000**
	(Middle land)	100.5	2	50.3	0.1	0.877ns

Aboveground – crown and stem carbon stock of trees, belowground – root carbon stock of trees, **significant at 99%, *significant at 95%, ns – not significant

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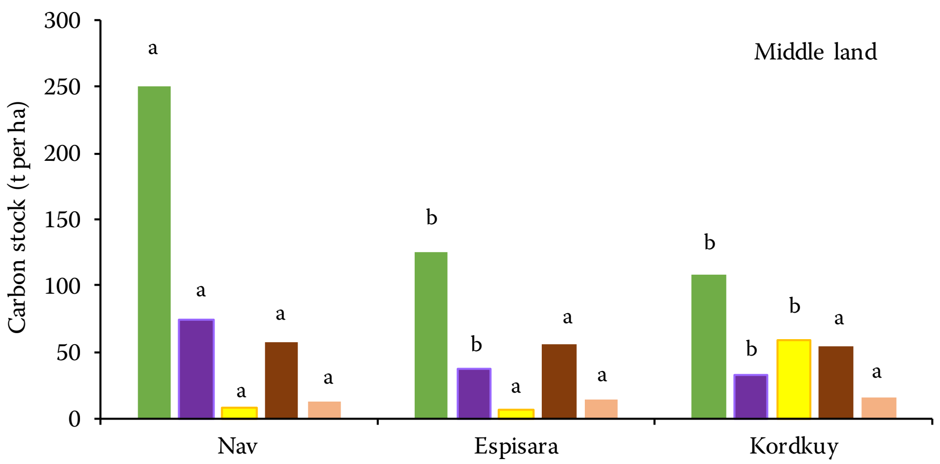

Figure 2. Carbon stocks of different sections of forest in the middle land (400–800 m a.s.l.) of the study sites

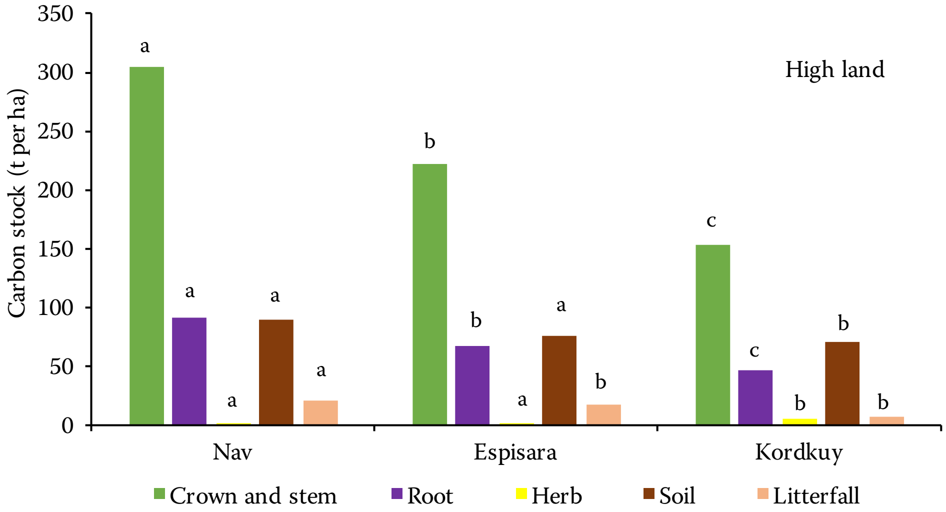

Figure 3. Carbon stocks of different sections of forest in the high land (1,500–1,850 m a.s.l.) of the study sites

in the values between the amounts of stem and crown carbon and root carbon in the middle and high land of Nav were meaningless but significant at the other two sites. The differences between middle and high lands in soil carbon stock were significant at all three sites. In the litter section, significant differences were observed only between the middle and high land of Kordkuy, unlike the other two sites, they had a general decreasing trend ($P \leq 0.05$) (Table 5). The Mann-Whitney U test for

Table 5. T-test results of carbon stocks in different sections of the forest between high land and middle land at study sites

Site	Carbon stock source	Mean difference	df	F	t	Sig.
Nav	crown and stem	48.9	46	2.30	1.49	0.143^{ns}
	root	14.7	46	2.29	1.49	0.143^{ns}
	soil	32.9	46	0.11	7.96	0.000**
	litter	8.1	46	0.54	1.81	0.77^{ns}
Espisara	crown and stem	86.8	54	1.76	4.62	0.000**
	root	26.0	54	1.76	4.62	0.000**
	soil	19.5	54	14.06	5.05	0.000**
	litter	3.5	54	2.86	1.18	0.243^{ns}
Kordkuy	crown and stem	41.2	34	0.01	2.22	0.033*
	root	12.3	34	0.01	2.22	0.033*
	soil	16.7	34	4.47	2.07	0.000**
	litter	9.2	34	25.86	2.81	0.016*

**significant at 99%, *significant at 95%, F – F-test, t – t-test, Sig. – significance, ns – not significant

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Table 6. Mann-Whitney *U* test results for herb carbon stocks at the study sites

Site	Carbon stock source	Mann-Whitney *U*	Wilcoxon *W*	*Z*	Sig.
Nav	Herb	168.0	574.0	–2.56	0.01*
Espisara	Herb	48.0	576.0	–5.76	0.000**
Kordkuy	Herb	90.0	300.0	–2.25	0.025*

**significant at 99%, *significant at 95%, *Z* – score, Sig. – significance

the herbaceous section also showed significant differences between the middle altitude and high altitude of all sites ($P \leq 0.05$) (Table 6).

DISCUSSION

Based on the results, there is a noticeable difference in carbon stocks between forests in northern Iran. The highest amounts of tree carbon and soil carbon were observed in the western part of these forests (Nav). Climatic study of these forests moving from west to east suggested decreasing precipitation, relative humidity and increasing temperature and evapotranspiration and climate change from humid and very humid in the west to the Mediterranean in the east in the horizontal range of these forests. This leads to reduced growth and reduced tree number per hectare in these forests (Marvie-Mohadjer 2012). Overall, estimated carbon was higher at higher altitudes in all selected sites, indicating a significant effect of altitude on carbon stocks in these forests. According to the characteristics obtained for other parameters in these forests, the same trend is also observed for the parameters involved in carbon calculations, especially number per hectare, basal area, height, diameter at breast height. We also see changes in forest types, changes in tree species and simultaneous reduction of socioeconomic issues and damaging factors such as human and animal presence with increasing altitude (Sefidi et al. 2011). However, outputs in this type of study are different, especially in temperate forests (Kumar et al. 2013). Zhu et al. (2010), in a study in Changbai Mt. in northeastern China, stated that with increasing altitude the amount of carbon stock in vegetation decreased significantly. The results of a study by Yu et al. (2014) on forest carbon stock in temperate forests in northern China showed that the ecosystem carbon stock including vegetation, soil and litter had an overall increasing trend. But at the local, regional, and global scales carbon stocks are affected by a large number of variables such as species, forest type, climate, topography, soil physical and chemical properties as well as ecosystem management and they usually have high spatial variability (Alvarez-Davila et al. 2017).

In soil carbon calculations, the overall results of carbon stock in surface soil (0 to 30 cm depth) of forests in northern Iran have the same decreasing trend of tree carbon from west to east, increasing with altitude and having the highest values in Nav. The increase in soil organic carbon with altitude is a result of higher amounts of organic matter input from underground and aboveground biomass, in addition low and slow decomposition due to lower temperatures and greater transfer of organic matter to deeper layers, possibly due to more precipitation in elevated zones, can be seen in higher zones (He et al. 2016). Soil organic matter can be increased or decreased based on a variety of factors including climate, vegetation type, available elements, disturbance and land use, and management performance (Sheikh et al. 2009). The higher the organic carbon content of the soil, the more carbon is sequestrated (Djukic et al. 2010). The research of Fahim et al. (2013) showed the highest amount of soil carbon at a depth of 0 to 20 cm in Kheyroudkenar beech forests in northern Iran. This is in agreement with the results of the present study in comparison with broadleaf mixed forests in middle land. Zhang et al. (2011) also reported that total soil carbon in the upper 20 cm layer of soil in the northern aspect of the Changbai Mountains increased with increasing altitude but in contrast to Djukic et al. (2010) in the Australian Alps that the maximum soil carbon was observed in low land. At Nav site in the west with reduced temperatures and increased rainfall especially at high altitudes, the reduction of sunlight due to the greater number of trees per hectare and the more closed canopy make litter-degrading microorganisms less active. Litter is the main source of organic carbon in the forest floor. Subsequently, the slower rate of biogeochemical cycles reduces the rate of litter decomposition. This will generally allow for higher soil organic carbon accumulation at this site. According to the results

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obtained at higher altitudes, annual litter values and carbon accumulation increased in this section, however, there was no significant difference between altitudes in the two study sites. The findings of the present study also illustrated that the amount of herbaceous carbon was higher in middle lands due to the openness of the canopy. The percentage of canopy cover has a significant effect on soil carbon content due to changes in moisture and heat conditions. As the canopy increases, the soil moisture also increases (Vahedi et al. 2016). In beech trees, soil moisture content increased and litter accumulation increased and herbaceous cover decreased, despite their higher number per hectare and canopy cover. At Kordkuy site, due to the lower number of trees per unit area, canopy cover was lower compared to the other two sites, and the herbaceous productivity increased. However, litter accumulation may be influenced by the environment and structure of the plant community and ecosystem processes (Lu, Liu 2012).

CONCLUSION

The results of this research demonstrated that the highest values of the estimated total carbon stocks were found in the high land, in the west in Nav (508,32 t per ha) and the highest values were observed in the middle land at the same site (402,84 t per ha). Therefore, there is an increasing trend in the horizontal range of these forests from east to west. The middle region, Espisara, is intermediate. Therefore, the western parts of these forests have a higher potential of total carbon stocks. In the vertical expansion range of these forests there is also an increasing trend at all three sites. This is closely related to changes in climate variables moving along the longitudinal range of these forests, whereby moisture content increases from east to west and there are decreases in temperature and drought period. Investigation of the carbon trend along the altitudinal gradient at all three sites indicates the effect of altitude on it. In addition, number per hectare, tree (crown, stem) volume and basal area are important predictive parameters for estimating carbon stocks, while in the present study these differences were also quite noticeable and were effective in the results. These findings have been present in both the aboveground and belowground sections. Much of the difference in carbon stocks at different sites is due to differences in soil and climatic conditions, but many biotic and abiotic factors also affect calculations of carbon stocks in forests and make it difficult to compare results. However, in selecting the study sites of the present study, it has been attempted to select the least disturbed areas and other damage. Therefore, the narrow strip of broadleaved forests of northern Iran as an ancient forest ecosystem is a huge carbon pool, and recent findings have shown these forests can assist in the accumulation and storage of CO_2. Therefore, stricter and more precise legal and scientific criteria are necessary to properly manage and preserve these valuable resources. Solutions such as reducing deforestation, increasing protected areas, changing forest management, reducing forest fires, planning for afforestation and forming NGOs will be very useful.

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