American Journal of Environmental Sciences 5 (3): 346-351, 2009
ISSN 1553-345X

A Study on Potentiality of Carbon Storage and CO_2 Uptake in the Biomass and Soil of Coppice Stand

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Abstract: Problem statement: Enhancing carbon storage in terrestrial ecosystems, especially in the forests, is a key factor in maintaining the atmosphere's carbon balance. With regard to the importance of forest in carbon sequestration, this study attempted to investigate the carbon storage potential and CO_2 uptake in oak coppice stand. **Approach:** After combining slope, aspect and hypsometric maps, the number of land units (polygons) as well as their areas were determined. Then 60 sample trees were selected in such a way that all environmental and typological conditions were taken into account. After determining the overall weight of different parts of tree, to measure the dry weight as well as to determine the amount of biomass, different parts of tree were transformed to a kiln. The humus was collected and weighted in an area of 400 cm^2 under each tree. The quantity of ash was taken away from biomass, then the amount of organic sequestrated carbon as well as that of CO_2 uptake was measured. To determine the amount of carbon stored in the soil samples were extracted from the depths of 0-10 and 10-30 cm. **Results:** The amount of organic sequestrated carbon was 22.65 tons ha^{-1}. The trunk, root, branch, soil, leaf and humus had the maximal amount of storage respectively. The annual carbon dioxide uptake was 5.94 tons ha^{-1}. **Conclusion:** Coppice stands had massive plant coverage as well as an increase in biomass production if the destructive factors were removed from these areas.

Key words: Carbon sequestration, CO_2, coppice stand, biomass, oak tree, Khalkhal

INTRODUCTION

The universal phenomenon of global warming originates mainly from continual increase in the production of greenhouse gases such as CO_2, fossil fuels consumption, forest destruction, irregular grazing of pastures, land use change and some other activities resulting in human life development[4]. The density of greenhouse gases increased considerably during the period of industrial revolution, especially in the contemporary century when the concentration of carbon dioxide rose from 280 ppm before industrial revolution to 386 ppm in 2006. Carbon dioxide is one of the most important greenhouse gases that gradually increase the temperature of the Earth. Climatic changes lead to the decline of carbon uptake by plants which may finally result in a considerable decrease of soil carbon storage to 11% by the year 2100[5]. In terrestrial ecosystems, plants are regarded the most important Co_2 up-takers. Plants absorb CO_2 from atmosphere and store it in their biomass during a photosynthesizing process. Some of the stored carbon is emitted into atmosphere during respiration and the difference between these two is called net primary productivity.

Since the rate of respiration is high in older forests, the annual uptake of carbon in these areas is low. The difference between the absorbed carbon and that of emitted is called" carbon sequestration " which is recognized as a very important universal issue[10]. The forests in China store annually 118.1 million tons of carbon as a result of growth of trees as well as storing 18.4 million tons in the soil but they release 38.9 million tons of carbon in the atmosphere. So, the pure uptake of carbon would be 97.6 million tons[11]. Forest as one of the major components of terrestrial ecosystems, plays an important role in energy matter and momentum exchange between the land surface and atmosphere. About 75% of carbon storage in such ecosystems is taken up by forest[3]. Likewise, 40% of total carbon storage is spread on trunks of trees, 27% on humus, branches and other wooden products and the rest on soil and forest floors[10].

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With regard to the amount of carbon storage, there is a direct relationship between soil fertility, leaf surface index, trees growth and biomass level[1]. For instance, the level of stored carbon in *Eucalyptus camaldulensis* afforested in Iranian southern city of Fassa in fertile growing land was estimated to be 3.67 tons ha^{-1} whereas in less fertile growing land it was only 2.27 tons ha^{-1} in a year.

Carbon purification or refining with artificial methodologies such as filtering, etc. is costly. For example, in the U.S.A, the estimated cost for each ton of carbon would be 100-300 US dollars[2]. Most of the carbon absorbing cost is spent on preserving and protecting the forests which is about 46.6-260.3 US dollars per ton[7].

By examining and measuring the level of carbon sequestrated in a biomass as well as in the soils of forests with different stands and types, it is possible for us to assess whether the cost of scientific management or control over these resources and increased contraction of heaps of soil can be reverted through CO_2 uptake in plant organs or not. The investigations show that the ever green wide-leaved forests have much further potentials to emit Co_2 and directing needle-leaved forests into those of wide leafs can increase the rate of carbon absorption[7]. Similarly, the amount of carbon storage in plants' biomass in controlled forests is 335 tons ha^{-1}, in traditionally controlled forests it is 145 tons and in pastures this would be 46 tons ha^{-1}. Storing takes place up to the depth of 40 centimeters below the soil surface[6].

Given the fact that dominant species in the area of study was oak tree and also considering that this tree exists in different types and stands, especially in the form of oak coppice, it is possible to claim that the results of the present study can be generalized to Zagross, another forest with the same quality locating at the west of Iran.

MATERIALS AND METHODS

The study area covers 278.4 ha of Khalkhal forest in the northern Iranian Province of Ardebil. This area extends from 48°34’38 to 48°36’16 latitude and 37°38’43 to 37 ° 40’60” longitudes. It has an altitude of 1980-2527 meters above the sea level.

Based on meteorological statistics, the annual level of rainfall in the area is 384.6 mm and the average temperature is 7.8°C. The minimum mean temperature is -3.8°C in January whereas the maximum mean is 20.1°C in August. The annual potentiality of evaporation and perspiration is 1200 mm and freezing weather encompasses 92.5 days a year. Based on Ambrege methodology as well as taking the ratio of $Q_2 = 57.2$ into account, this area is classified under the category of the cold and semi-humid climate. From June to September, we are witnessing the dry months in this region.

During regional investigation, fifteen trees and shrub species and seven forest typologies were identified in the stand under study. *Quercus macranthera* and *Acer campestre* are the most plentiful available species in the area. Pure oak type and the oak with maple constitute more than 82% of the stand.

Having used Global Positioning System (GPS) for identifying the situation of forest areas limit and laying it down on the topographic map, the covering area of Geographical Information System (GIS) perimeter was identified and the maps of aspect, slope and altitude of the region were studied. Then, through forest walking, the tree shrub species of the area were collected and identified. Plant covering map of the area was drawn based on the canopy and the vertical image of aerial organs down to the ground.

Based on the canopy density, the region was divided into five classes less than 5, 5-25, 25-50, 0-75% and more than 75%[8]. The map of the forest typology was provided based on the percentage of species canopy.

After combining the maps of canopy density, slope, the aspect and altitude, a number of polygons and their areas were identified. The 60 harvest shoots were selected and spread in such a way that all environmental and typological conditions of stand could be precisely taken into account.

The samples were laid up randomly on selected polygons and then these regions were slabbed on a designed area using GPS and number of shoots in designed groups. To investigate how many shoots are grown ha^{-1}, statistics was collected from stand randomly with quadrant plots and 1500 m^2 area[12]. The bases taken at every polygon were considered as the center of each plot. The specified samples were extracted just at the end of growth period before the fall in September.

After slabbing the samples, the thickest shoot was determined as the main base and other ones as branches. By digging the soil around the log, the main and secondary roots which had more than 1mm diameter were collected.

Considering the average diameter of oak bases and the estimated ages of disks in different sizes, the average age of mass was estimated. The wet matter of the organs such as trunk, branch, root, leaf and humus were exactly measured in gram scale and for determining the dry matter, the parts of tree were transformed to the oast and were kept there for 3 days in a temperature of 80 degrees centigrade. Then they were weighted again in gram scale. In this case we could determine the biomass amount of the aerial and underground organs. By burning aerial and ground organs their ash weight was determined. After deducting the ash weight from the biomass, the level of organic carbon saved in the bases was calculated.

After operating the coefficient 44/12[9] in the level of reserved organic carbon in different organs, the level of absorbed Co_2 during the period of mass growth was calculated. To calculate the weight of humus, the sub-bases at a level of 20×20 cm^2 of available humus were collected and their weights were determined up to 1 g precision. The destiny of the covering crest of every polygon was generalized to a level of 1 ha. To determine the amount of carbon stored in the soil samples were extracted from the depths of 0-10 and 10-30 cm. In order to generalize the amount of carbon in the measured samples to the whole area of study, the specific apparent weight of the soil was measured in the lab. For data analysis, SPSS and PC-ORD statistical software were used in this study. To compare the mean level of stored carbon with absorbed Co_2 in organs with different densities, Duncan test was applied in the present study.

RESULTS

The diameter and height means of oak tree species in the stand under study revealed to be 3.23 cm and 2.18 m respectively which shows the fact that the means will increase if the density of growth level increases Table 1. Given the average age of stand (14 year), the annual growth of diameter and height was determined to be 0.23 and 15.6 cm.

The average annual biomass ha^{-1} was estimated to be 1.58 tons which showed that the above-ground biomasses were higher than those laid underground.

Table 1: The results of quantitative study of oak species of the studied stand

Crown canopy density (%)	Forest area* (ha)	Diameter Basement** (cm)	Diameter 1.30** (cm)	Height** (m)
< 5	45.1	5.10	2.558	1.765
5-25	74.3	5.477	2.991	2.109
25-50	38.2	5.575	3.139	2.179
50-75	44.2	5.734	3.502	2.502
75 <	76.6	6.055	3.941	2.542
Mean***		5.590	3.230	2.183

*: The occupied area by each level of crown canopy density in the studied stand; **: The average diameter basement, diameter at breast and base height in different crown canopy densities of the studied stand; ***: The average diameter basement, diameter at breast and base height in the studied stand

It also showed that the greatest level of biomass is stored in the trunk Table 2. The weight of ash in different organs of oak species equals 10.9% of the dry weight. Such proportion exists 11.2% in the trunk, 11% in the branch, 9.2% in the leaf and 8.9% in the root.

The annual level of stored organic carbon in the biomass of the plant organs as well as in the soil is averagely 1.83 tons ha^{-1}.

Among different organs those that have the highest level of carbon reserves are trunk, root, branch, soil, leaf and humus respectively. This level in aerial organs is twice as many as that of underground organs. The absorption rate of Co_2 at every hectare of stand is averagely 5.94 mega grams per year. Such amount at the layers with the density range of 1-5 would be 1.17, 3, 4.5, 9.46 and 11.53 mega grams respectively Table 3 and 4. The results of Duncan's test showed that the level of stored carbon and that of assimilated Co_2 ha^{-1} in all layers canopy density differed significantly Table 5 and 6. We studied different regression equations between the biomass of aerial organs and diameter breast and height of the trees and finally selected the one which showed the highest correlation coefficient among the parameters Fig. 1 and 2.

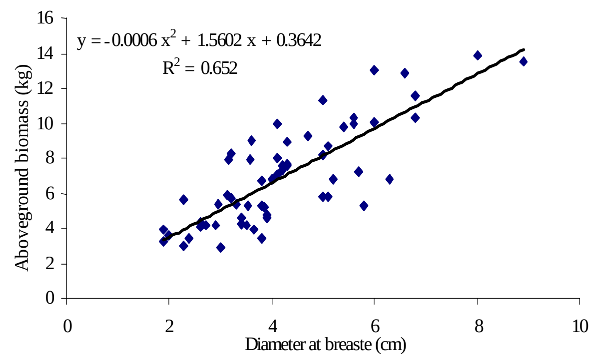

Fig. 1: The correlation between diameter at breast and biomass in the studied stand

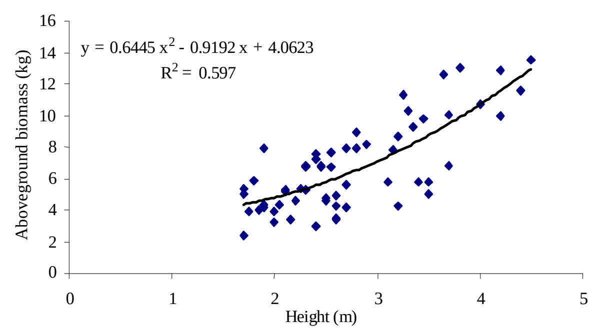

Fig. 2: The correlation height of the tree and biomass in the studied stand

Table 2: Annual amount of biomass storage in aerial and underground organs from different crown canopy densities of the studied stand ha^{-1}

Crown canopy density (%)	Trunk Biomass* ton ha^{-1}	Branch Biomass* ton ha^{-1}	Leaf Biomass** ton ha^{-1}	Root Biomass* ton ha^{-1}	Humus Biomass** ton ha^{-1}	Aboveground Biomass ton ha^{-1}	Underground ton ha^{-1}	Total ton ha^{-1}
< 5	0.041	0.0440	0.0100	0.047	0.0003	0.0950	0.047	0.1423
5-25	0.268	0.2100	0.0500	0.248	0.0070	0.5280	0.248	0.7760
25-50	0.382	0.2760	0.0710	0.456	0.0580	0.7290	0.456	1.1850
50-75	0.947	0.7170	0.1960	0.777	0.1340	1.8600	0.777	2.6370
75 <	1.220	0.8000	0.2340	0.912	0.2700	2.2540	0.912	3.1660
Mean	0.572	0.4094	0.1122	0.488	0.0940	1.0932	0.488	1.5810

*: The amount of biomass stored in trunks, branches and the roots of the trees in the crown canopy stand was determined and via dividing it by the average age of the stand (14 years), the amount of the produced biomass per year was computed; **: Since the production and falling of the leaves and decomposition rate of the humus differ annually, the biomass amount of the leaves and humus was taken into account just for the year in which this study took place

Table 3: CO_2 uptake in aerial and underground organs in the crown canopy of the studied stand

Crown canopy density (%)	Trunk* (Mg ha^{-1})	Branch* (Mg ha^{-1})	Leaf** (Mg ha^{-1})	Root* (Mg ha^{-1})	Humus** (Mg ha^{-1})	Aboveground Biomass (Mg ha^{-1})	Underground Biomass (Mg ha^{-1})	Total (Mg ha^{-1})
< 5	0.136	0.137	0.320	0.159	0.001	0.593	0.159	0.753
5-25	0.882	0.690	0.170	0.819	0.020	1.742	0.819	2.581
25-50	1.254	0.911	0.237	1.526	0.165	2.402	1.526	4.093
50-75	3.070	2.330	0.651	2.605	0.383	6.051	2.605	9.039
75 <	3.951	2.606	0.741	3.037	0.772	7.298	3.037	11.107
Mean	1.859	1.335	0.420	1.630	0.268	3.617	1.630	5.515

After deducting the ash weight from the biomass of the organs, the amount of organic carbon was computed and by operating the coefficient 44/12, the amount of CO_2 stored by each organ was estimated. *: The amount of CO_2 stored in trunks, branches and the roots of the trees in the crown canopy stand was determined and via dividing it by the average age of the stand (14 years), the amount of annual CO_2 uptake was estimated; **: Since the production and falling of the leaves and decomposition rate of the humus differ annually, the amount of CO_2 stored by the biomass of the leaves and the humus was taken into account just for the year in which this study took place

Table 4: The percentage of organic carbon, carbon storage and CO_2 uptake in the soil of the study area

Soil depth (cm)	Organic carbon percentage	Soil specific weight g cm^{-3}	carbon storage* (ton ha^{-1})	CO_2 uptake* (Mg ha^{-1})	CO_2 uptake** (Mg ha^{-1})
0-10	2.43	1.35	0.500	1.833	0.131
10-30	2.24	1.40	0.922	4.057	0.290
Total			1.422	5.890	0.421

*: The amount of carbon storage and CO_2 uptake in the soil of the studied stand during the growth period; **: The annual amount of Co_2 uptake in the soil of the studied stand

Table 5: Analysis of variance of CO_2 assimilation in biomass of the oak species

	Sum of squares	df	Mean square	F	Sig.
Within groups	7834.879	4	1958.7200	43310.793	0.000
Within groups	0.192	58	0.0033		
Total	7835.071	62			

Table 6: Duncan test results on annual carbon assimilation in the studied areas with different densities ha^{-1}

		Subset for alpha = 0.01				
Density	N	1	2	3	4	5
< 5	12	1.174				
5-25	18		3.002			
25-50	8			4.514		
50-75	11				9.460	
75-100	14					11.528
Sig.		1.000	1.000	1.000	1.000	1.000

DISCUSSION

Oak coppice has encompassed more than 5 million hectares of the Iranian forests. Unfortunately, factors such as irregular harvesting, presence of live-stocks and cattle's in the area, altered application, etc. accelerated the destruction of oak coppice forests. Coppice forest can be a good choice for carbon sequestration by increasing biomass of wood plants.

The annual diametrical and height growth rate of the studied oak trees are 0.23 and 15.6 cm respectively which indicate that the higher the rate of density is, the more the rate of growth would be. The level of produced biomass ha^{-1} is averagely 1.58 tons a year in such a way that the density of 75% and over is 24 times greater than the density which is less that 5%.

Out of total biomasses, 65.2% are stored in aerial organs, 29.2% in underground organ and 5.6% in humus.

Areas in which the density of canopy was less than 25% in particular in southern slopes, had no humus. Organic carbon that is stored in different organs during the growth period has been estimated to be 21.23 tons ha^{-1}. This quantity in densities which were less than 5, 5-25, 50-75% and more than 75% reported to be 1.77, 9.85, 15.63, 34.52 and 42.4 tons ha^{-1} respectively. The amount of carbon storage in the soil of the study area was estimated to be averagely 1.42 tons ha^{-1}. The stand under study absorbed annually an average of 5.52 mega grams of CO_2 from biomass and 0.42 mg from the soil, therefore the annual mean of CO_2 absorption is 5.94 mg ha^{-1}.

As far as the level of density increases, the rate of uptake will grow intensively. Significant differences at different densities were reported in such a way that the level of absorption at densities 5-25% will be more than 5 times as many as the densities which are less than 5%. The levels of uptake on the trunk, root, branch, soil, leaf and humus are 1.86, 1.63, 1.34, 0.421, 0.42 and 0.27 mega grams respectively. This shows that the maximum storage occurred in the trunk whereas the minimum storage happened in the humus. The comparison between the results of this study and that of Boom Abad Co. Ltd shows that the level of CO_2 uptake in the Oak coppice stand in Khalkhal was higher than those grew in western Iranian oak forests. This difference may arise from the higher fertility of soil due to condensed plant covering in the studied area. The chi-square results show that there is a significant relationship between the biomass of the aerial as well as underground organs and the altitude of the study area. Other physiographical factors such as slope and aspect did not affect the biomass. In other words, physiographical factors except altitude do not have any serious impact on the biomass amount. Since there is no specific pathways for both human beings and animals at higher altitudes, the amount of diametrical and height growth has increased which leads to increased in biomass production. Among the stand characteristics, the relationship between plant coverage and biomass amount was significant.

The results show that Zagross (An area in the west of Iran with high mountain ranges as well as dense forests) forest can absorb 3.25 tons of Co_2 ha^{-1}. The annual value of gas adjustment of this forest is estimated to be 250 US dollars ha^{-1}. Kirby[6] study shows that protecting the forests and preventing them from changing into pastures have a positive effect on increasing the amount of carbon storage in controlled forests.

Given the fact that every hectare of mass stores an average of 1.58 tons of carbon annually in one hand and artificial refining of carbon which is estimated to be 200 US dollars[2] on the other hand, the environmental cost of an area of 278 ha during the growth period estimated to be 1,250,000 US dollars which showed to be much more greater than the cost of maintaining and preserving the stand.

Generally, there exist complicated problems such as mineralized organic substances and climatic factors effects on CO_2 absorption. Therefore, it is necessary to carry out an extensive research to investigate the potentiality of natural factors and those of afforested for storing carbon in other growing areas in Iran. It also seems fruitful to investigate the effect of secure and protective operations on determining the rate of carbon storage change in different forest stands. Actions must be also taken to examine the process of how reserved carbon is re-circulated to the organ and different parts of stand and how to find solutions for minimizing the rate of this regression to the atmosphere. We can also take drastic steps to lower the production of greenhouse gases.

CONCLUSION

Coppice stands can have massive plant coverage as well as an increase in biomass production if the destructive factors are removed from these areas. Moreover, soil preservation and mass production of natural wood will be other signs of preserving these areas. Meanwhile nobody can ignore the effective role of coppice stands on controlling and balancing the spread of atmospheric gases. Because of having substantial amount of carbon storage, coppice stands can considerably reduce the negative effects of greenhouse gases. Therefore, serious attempts should be made to keep, preserve and enrich these natural resources which play a very vital role in the terrestrial ecosystems.

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