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The soil carbon sequestration capacity with different land uses (case study: the award watershed in Mazandaran Province)

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Abstract

One approach for reducing CO2 and increasing global carbon storage is the sequestration of it in soils. Therefore, this study aims to evaluate carbon sequestration with different land uses and its economic aspect in the Award watershed in the Mazandaran province. First of all, in the study area, the boundary of the watershed was delineated and controlled by a field survey using GPS. After the boundary of the study area was demarcated, the soil samples were selected randomly, taken from a depth of 0-30 cm for each land use (i.e., protected forest, open forest, rangelands, walnut gardens, mixed walnut–apple gardens, cereal croplands and frijol farmland). In total, around 21 soil samples were taken from the study area. The selected parameters for analysis are the amount of carbon sequestration and certain soil properties (bulk density and organic carbon). The statistical analysis was performed by the SPSS.16.0 software. After the assessment of the homogeneity of variance, in order to test the null hypothesis of the equal averages of the parameters for the seven land uses, analysis of variance (ANOVA) was performed by the Duncan test at a significance level of 5%. The results demonstrate that the different land uses have different effects on the amount of carbon sequestration. The protected forests and cereal croplands have the highest and lowest carbon sequestration values, respectively. The overall amount of carbon sequestration in this watershed has been estimated to be around 743,460 ton/ha.

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Introduction

The growing population needs the certain resources, such as water, food and land, but these are scarce on the Earth. Another issue that matters is the quality of the resources; therefore, human beings need proper conditions for a clean atmosphere and healthy food. Nowadays, the increase in fossil fuel consumption, land use changes and vegetation deterioration have led to the release of large amounts of greenhouse gases into the atmosphere (IPCC, 2001), leading to various problems such as air pollution and temperature increases in other words, climate change as a whole. Since 75% of the carbon in semi-arid and arid ecosystems is stored in the soil, an optional approach for reducing CO_2 and improving global carbon storage is its sequestration in soils Carbon sequestration is a procedure for absorbing extra CO_2 from the atmosphere, and one approach involves transforming it into organic matter, such into the aerial and underground organs of plants, especially by the planting of resistant species of plants in rangelands. There are many studies about the usefulness of corrective operations - such as the protection and planting of green vegetation in rangelands -on carbon sequestration; as Derner *et al.* (1997) compared the amount of the carbon sequestration in two depths of 0-15 cm and 15-30 cm of surface soils in the two different areas of the protected and grazed rangelands. Their results indicate that the carbon sequestration in grazing areas is more than in non-grazed areas at a depth of 0-15 cm, but there were no statistically significant differences between the two. Schuman *et al.* (2002) evaluated corrective management operations, such as fertilization and grazing in the United States, and they found that these operations increased the level of carbon sequestration as well. Ojima *et al.* (2000) studied the effect of croplands and rangelands on carbon storage; he concluded that the overuse of rangelands and their conversion into farmland increased the erosion and sediment rates, but they caused a reduction in the carbon sequestration potential.

On the other hand, in this study was measured the effect of management practices on carbon sequestration in soils. It is also presented as an indicator to assess the performance and potential of the watershed as well as for sustainable development. Soil carbon sequestration allows for the replenishment of soil organic matter and, provides several other benefits including improved soil structure and stability that leads to reduced soil erosion, improved soil biodiversity, increased nutrient holding capacity, increased nutrient use efficiency, increased water holding capacity, increased crop yields and profitability and potential marketability of the sequestered carbon.

Material and methods

Study area description

The Award watershed is in the Mazandaran province, located between longitudes 53° 42' 37"E to 53° 57' 18"E, and between latitudes 36° 35' 40 N to 36° 39' 5"N. This watershed covers a total area of 9,410/74 hectares, and it is a sub-basin of the Neka River basin, which is located to the east of Mazandaran and South Glogah. The villages in the watershed include Award, Nyala, Yakhkesh, Sefid Chah, Pjym and Ramedan. According to the land morphology and landforms, this watershed is a mountainous watershed overlooking the River Neka valley. Since this watershed is a non-hydrological basin and is composed of both independent and connected units, there is no unique mainstream here. Nonetheless, the River Neka, which exists along the southern borderline of the basin, can be considered to be the mainstream - at 1,400 metres length, it originates from the northern highlands and passes through the middle of the basin to exit from the southwest of the basin output. Based on the Emberger classification, the Award watershed has a cold Mediterranean climate, and according to the De Marton method, it is a semi-humid climate. The average rainfall in the basin is around 459 mm per year, falling mainly in the form of rain. The average temperature in the study lowest temperatures occur in January, and the hottest temperatures are in July. Because of a proper spatial distribution of villages in the watershed, the products of agriculture, gardening and animal husbandry are adequate, and the highlands of the study area reach around 11.46 °C. The have relatively rich vegetation as well.

Field survey and soil sampling

In this study, by first using the Google Earth software, the boundary of the watershed was delineated and controlled through a field survey using GPS. The total watershed was selected as the study area and soil samples were taken randomly from a depth of 0-30 cm for each land uses (i.e., protected forest, open forest, rangelands, walnut gardens, mixed walnut–apple gardens, cereal croplands and frijol farmland) . Samples were obtained from seven points with three replications in each spot. Finally, 21 soil samples were collected from the study area and then transported to the laboratory. The samples were dried and put through a 2 mm sieve. To determine the bulk density of the soil, an aggregate series of each horizon was taken, and the bulk density of each sample was determined by the aggregate and the paraffin methods Black and Hertage (1986). The organic carbon of the soil was measured by oxidation using potassium dichromate (Nelson, 1982). Via this method, the soil organic carbon (gr C/Kg soil) was calculated based on the organic carbon percentage (%OC) of the soil.

To estimate the content of the carbon and its total mass (weight) in the soil, it was calculated carbon rather than its percentage, based on the carbon content (g) in the soil unit (kg), as shown in Equation 1.

$$OC_{(grC/Kg\ soil)} = \%OC \times 10 \quad (1)$$

Where OC is the amount of soil organic carbon in one gram of carbon per kg of soil, and OC% represents the organic carbon percentage of the soil. Having a weight of organic carbon per soil weight unit (gr C/Kg soil), the soil bulk density and its depth, the organic carbon per unit area is calculated by Equation 2 (Pimental, 1997).

$$SC = e \times Bd \times OC_{(grC/Kg\ soil)} \times 10 \quad (2)$$

Where Sc indicates the amount of carbon in the soil in ton/ha at a certain depth, and e is the soil depth (meter). OC represents the organic carbon mass in for a gram of carbon per a kilogram of soil, and Bd denotes the soil bulk density for a gram per cubic centimetre.

The statistical analysis of the data was performed using the SPSS 16.0 software. Initially, the normality of the data was checked, including the existence of outliers. After the homogeneity of variance test, in order to test the null hypothesis of being equal averages in seven land uses, it was carried out the analysis of one way variance (ANOVA), then in order to compare their means; Tukey's test was used at a 5% significance level.

Results and discussion

The organic carbon of soil

Organic material is an important indicator of the fertility of the soil, which is important to improving the bio-physicochemical characteristics of the soil. The organic matter has been considered as a main indicator of soil quality (Reeves, 1997, Lal, 1997). Carbon has been stored as the soil's organic matter, but its storage is affected by intensive farming and the overexploitation of land. When forestlands are converted to croplands, the amount of organic carbon in the soil is reduced, even though its rate is controlled by certain effective agents, such as climatic factors and the intensity of cultivation.

The results (Table 1) indicate that the type of land cover has an influence on the soil's organic carbon as well as the soil organic matter as a whole. The statistics show statistically significant differences for seven different land uses (p value <0.05). The most important factor in the reduction rate of the organic matter in the soil is the tillage, which increases the rate of decomposition of the organic matter. The same Aguilar *et al.* (1988) indicated that the tillage made the low layers of the soil with lower organic matter mix with the topsoil with a higher organic matter mix; as a result, the organic carbon of the topsoil is reduced Lal (1999). It is argued that the severe, intensive use of the land reduces the surface cover amount and, therefore, decreases the quality and quantity of the organic carbon in the soil. Consequently, the soil's organic matter is an indicator of the healthiness and quality of the soil, and management and corrective activities (Lal, 1999, Farquharson *et al*., 2003) heavily influence it.

Table 1. The analysis of variance (ANOVA) of the carbon sequestration with different Land uses.

Variable Type	Sum of squares	df	Mean square	Sign.	F
Variance between groups	70.034	6	11.672	0.002*	6.325
Variance within groups	25.838	14	1.846		
Variance total	95.872	20			

*Significant difference at a 5% level; df represents the degree of freedom.

The carbon in the soil

The estimated results of carbon sequestration in an area unit (ha) for seven land uses are shown in Table 2. Each land use has a different effect on the carbon sequestration rate, and their differences are statistically significant at the 0.05 level. As such, the maximum amount of carbon sequestration per ha was observed in the protected forests, and the lowest amount of the carbon sequestration in the cereal farmland, as well (Fig.1).

The estimate of the soil's carbon sequestration shows that it varies the amount of carbon storage per area unit for each of the different treatments. So that the comparison of ANOVA test showed the significant differences in the carbon sequestration amounts in the different land uses, so that the highest values occur in the protected forest, but the lowest amount of carbon sequestration was in cereal cropland.

Table 2. The variations of soil properties in the depth (0-30 cm) in Award watershed.

Land Use	Carbon Sequestration (ton C/ ha)	Bulk Density (gr/cm3)	Organic Carbon (grC/kg soil)	Organic Carbon (%)
Protected Forest	257100[a]	10 [a]	85.7 [a]	8.57[a]
Open Forest	82500 [c]	10 [a]	27.5 [b]	2.75[b]
Walnut–Apple Garden	75600 [c]	7 [a]	36 [b]	3.60[b]
Walnut Garden	91200 [c]	8 [a]	38 [b]	3.80[b]
Rangeland	112080[c]	8 [a]	46.7 [b]	4.67[b]
Frijol Farmland	74340[c]	7 [a]	35.4 [b]	3.54[b]
Cereal Cropland	50640 [b]	4 [a]	42.2 [b]	4.22 [b]

* Similar letters indicate no significant difference at the 5% level.

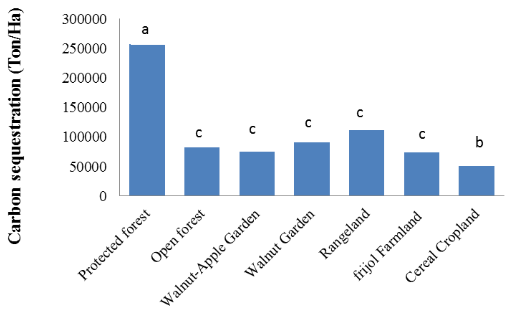

Fig. 1. The variations of the carbon sequestration (ton /ha) in the Award watershed.

Therefore, it can be suggested that forest ecosystems have a high capacity for carbon storage. In addition, the studies done by Bordbar and Mortazavi Jahromi (2006) have shown that the biomass of forestlands is directly related to carbon sequestration. The protected forest has the highest rates of carbon sequestration in the watershed. Ojima *et al.* (2000) studied the effect of croplands and rangelands on carbon storage; he concluded that the overuse of rangelands and their conversion into farmland increased the erosion and sediment rates, but they caused a reduction in the carbon sequestration potential. This approach will prevent land degradation and soil erosions, and will protect the land - it has a number of benefits for society. Obtained results are similar to Schuman and *et al* (2002) results.However, the rangelands of this watershed, covered by grass and bushes over the years, have been grazed extensively by domestic animals, and as such they exhibit a low degree of carbon sequestration per area unit. The results here indicate that there are many lands with low yields which are cultivated, especially in steep highlands. The results of this study reveal some significant differences in the amounts of organic matter in soils, but there are no significant differences in the soil bulk density after the conversion of forestlands into gardens and croplands. Based on these results, it was found that converting forestland into other types of land reduces the soil's organic matter and increases its bulk density. Consequently, according to this research, the forestlands to the south of the Caspian Sea need more attention and quickly, especially in order to protect these areas from land-use change. In addition, the low-yield lands must change to high-productivity gardening. It is recommended that these lands should be converted into productive gardens. Substantial resources could be mobilized through the implementation of different payments for watershed service, climate change mitigation through carbon sequestration, targeting the providers of those environmental and social services. Soil carbon contents depend on the main long-term factors of soil formation, but can be strongly modified (degraded or improved) by land use changes and land management. An increase in carbon sequestration causes an increase in the operational biodiversity and more effective soil biological functioning, which is normally very low in most agricultural soils. Soil carbon sequestration is good for the soil quality, both at short-term and long-term. It is a cost-effective and environmentally-friendly process that can be achieved through land management practices adapted to specific land uses

Conclusion

The variance of carbon sequestration is related to the type of management and the land use. In fact, the carbon sequestration potential is influenced by plant species, locations and management practices (Mortenson and Shuman, 2002). Broadly, in the watershed of Award, forestland has the highest biomass per unit area compared to the other regions. The estimates in the watershed of Award indicate that this area has a potential equal to 743,460 ton/ha for carbon sequestration. Assuming that the economic value of a ton of carbon sequestration is at least $50 Luciuk *et al.*, (2000); the total amount of annual carbon sequestration might be around $37,173,000. Therefore, as regards the conscious exploitation of watersheds, the amount of carbon storage could be an indicator of output for sustainable development. Therefore, an important activity to be included in the design of the proposed pilot activities would be directed at building more awareness at all levels to the prospects and potential benefits for carbon sequestration at local, national, regional and global levels.

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