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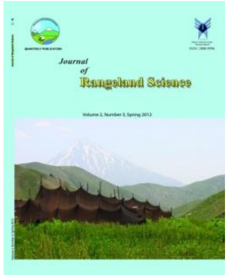

Full Length Article:

Effects of Topographic Factors on Carbon Sequestration in *Astragalus Gossypinus* (Case Study of Bazan Region, Kermanshah Province)

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Manuscript Received: 11/01/2012
Manuscript Accepted: 27/08/2012

Abstract. Increasing the concentration of atmospheric carbon dioxide is the main factor for the climatic change having some harmful consequences for the human health while there is no considerable effort for decreasing this accelerated global problem, yet. Kermanshah province located in the west of Iran has about 1,200,000 ha rangeland which is dominated by *Astragalus* spp as the more frequent shrub beingable for the carbon sequestration and more than 80%, its biomass has a key role in the carbon sinking into the soil layers. In order to investigate the effects of topographic factors on carbon sequestration, this study was conducted in the Bazan rangeland of Kermanshah province as the representative site. This site is characterized by the indigenous vegetation of rangeland. The maps including topography, vegetation and date layers were digitized by GIS (Arc GIS 9.1). In each homogeneous area of representative site, two or three linear parallel 30 m intervals were randomly established along the slope length and plant sampling for biomass was doneusing a quadrate plot (1×1 m) with 10 m plotting intervals. In addition, the highest rate (118.68 kg/ha) of sequestered carbon was observed in the altitude of 1900-2100 m above sea level in the northern direction while the lowest stored rate (39.13 kg/ha) was found in 1100-1300 m in the southern direction.

Key words: Carbon sequestration, Physiographical effect, Kermanshah province, Bazan region.

Introduction

Global warming is one of main concerns in current century and carbon dioxide is one of the most greenhouse gases resulting in global warming phenomena. This problem has many impacts such as the melting of polar ice, acid rain and consequently harmful effects on the organic lives which contributes to the destruction of the natural ecosystems and leads to the floods and drought, disturbs the climatic and ecological balances and eventually weakens the production potential. In 1998, approximately 5.5 billion tons of carbons were released into the air through fossil fuels. If this amount increases up to 3% on average in a year, it is expected to be 10 billion tons of carbon emissions in 2010 which results in the anthropogenic global warming and the destruction of the ozone layer. The conventional mechanism is how to curtail carbon and trap it into the soil. Carbon extraction is conducted in some biotic and non-biotic ways (Lal, 2003). The biotic approach of carbon extraction is for the plants to absorb the atmospheric carbon dioxide, convert it into biomass and then, transform it to the organic carbon or humus (Halman & Steinberg, 1999). In Iran, 84.96 out of 164 million ha of lands are in the form of range areas taken as the widest life lands of the country (FRWO, 2006). There are different types of biomass such as shrubs, forbs and grasses among which the shrubs are of greater magnitude because they contain biomass and tend to be basic carbon storage in view of sustainability and permanency. Since shrubs are fraught with the considerable root system biomass that exceeds 80% of the total weight of plant-derived biomass. They play a crucial role in the atmospheric carbon sequestration and transmission of the sequestered carbon into the soil layers (Rees *et al.*, 2005). Among the shrub species, *Astragalus* spp covers nearly 17 m^2/h of lands, 19% of the rangeland and 10% of the total area of Iran. *Astragalus gossypinus* species is highly beneficial in terms of soil protection, plant by production and biodiversity and also ecological terms such as carbon sequestration (Ma'soomi, 2001; Abdi, 2005). *A. gossypinus* species is abundant and widely grown in Zagrus mountain ranges, especially in Kermanshah province. Therefore, considering the amount of growth and the practical characteristics of such species in terms of the amount of carbon sequestration, it seems highly essential to carry out the carbon sequestration in the Zagrusareas in Kermanshah province. For that reason, the present study investigated the effect of topographic factors (the altitude slope directions) on the degree of potential carbon sequestration in Bazan site, Javanrood where *A. gossypinus* grows. The studies indicate that topography affects the carbon sequestration (Wei *et al.*, 2006; Rhoton *et al.*, 2006; Norton *et al.*, 2003) so that the impact will be due to the production of plant-derived biomass (Tatsuhara and Kurashige, 2001), the impact on moisture and temperature and the effect on the rate of fragmentation. In an investigation of the effects of land-cover type and topography on the soil organic carbon storage in China, Han *et al.*, (2010) argued that the slope direction affects the sequestered carbon in the ecosystems. In the investigation of the effects of climatic factors and altitude on the carbon sequestration potential of plant species growing in the north of Karaj river, Heidari *et al.*, (2010) concluded that the greatest amount of carbon sequestration belongs to 2250-2500 m above sea level with the annual precipitation of 400-450 mm. The soil carbon content varies in terms of the soil type, topography and applicability of land (Garten & Ashwood, 2002). Topography plays an important role in the changes of microclimate because of the impact of precipitation, temperature and sun light absorption (Wigmosta *et al.*, 1998; Brown *et al.*, 2004). Considering the organic carbon content and inorganic matter in some soils related to the slope aspect, Franzmeier *et al.*, (1969) suggested that there is a greater amount of the sequestered carbon in the northern direction comparing to other directions. Chen *et al.*, (2006) stated that topographic factors have had significant impacts on the climatic changes, and hence will be able to affect the movement and transference of the moisture depending on the landscape characteristics. Thus, the productivity of ecosystems is closely dependent upon topographic factors. Kleiss

(1970), Walker and Ruthe (1968) argued that the way the carbon is distributed in a typical ecosystem depends on a number of soil properties, all of which are affected by the slope factor. Anderson (1995) maintained that the concentration in the soil organic carbon is found to be less in the high slopes where there is maximum erosion and the greatest amount of organic carbon is observed in the low slopes with the concentrated sequestrations.

Preparation of topographic map and sampling

This site is characterized by the indigenous vegetation of rangeland. The maps including topography, vegetation and date layers were digitized by GIS (Arc GIS 9.1) for driving the homogenous area. In each homogeneous area of representative site, two or three linear parallel transects with 30 m intervals were randomly established along the slope length and plant sampling for biomass was doneusing a quadrate plot (1×1 m) with 10 m plotting intervals. Following the elevation, the main topographic aspects (north, south, west and earth) were selected within each elevation class and the altitude was categorized in five classes as follows: 1100-1300 m, 1300-1500 m, 1500-1700 m, 1700-1900 m and 1900-2100 m.

The study area was marked and the species having the widest surface, the greatest percentage of canopy cover and higher frequency in the dominant plant types were determined in the index area. In each representative unit of homogeneous area, first linear transects (depending on the surface of the homogeneous region) in the parallel intervals (30 m apart) were randomly placed on the slope using two woody pickets. The transects were offset having the length of 50 m on the slope from up to down with an angle of 45° down the slope. The quadrate plots of 1 m^2 were established at the surface with the distance of 10 m along the transects. Then, in each plot, plant sampling was carried out from the standing above ground biomass. For the measurement of underground biomass (root system), only a limited number of *A. gossypinus* plants was cut and the underground biomass weight of other samples was estimated using the sample linear regression (y=ax+b). Therefore, fifteen species of *A. gossypinus* were removed in different canopy covers via the excavation of the whole plant roots and a regression equation was established between the canopy covers and root biomass.

Plant analysis

First, samples obtained from the canopy and root parts were dried in the oven (at 70°C for 24 hours). The plant carbon content including the root and canopy biomass was measured through the combustion in an electrical furnace. For this purpose, the samples were placed into the furnaces and kept for 3-4 hours at 500-600°C in order to determine the change coefficient of the organic carbon sequestration of the aerial and underground parts of the herb. The total ash of each sample was weighed after they were cooled in a desiccator. After determining the ash weight and retaining the initial weight and the proportion of organic carbon to organic matters, the amount of organic carbon in each sample was calculated according to the following equation:

$$OC = 0.5\ OM$$

OC: Organic Carbon; OM: Organic Matters

The above relation states that half of the plant ashes includes the organic carbon and the other half is made of other elements.

To estimatie the underground biomass, a linear simple regression between the aerial carbon content and root biomass was calculated using SPSS19 software. Then, the data were subjected to one-way ANOVA. Mean comparing analysis was done among the carbon variables in each elevation with different aspects through NSK procedure at P= 0.05.

Results

The results obtained from the analyses of variances of carbon sequestration via *A. gossypinus* in 5 altitude classes and four topographical directions are presented in (Table 1).

The results of ANOVA analysis showed that in the first altitude (1100-1300 m), there were significant differences among the aspects for the amount of carbon sequestration (P≤ 0.01%). The higher and lower amounts of stored carbon with the average values of 101.55 and 39.13 kg/ha were obtained for the north and south directions, respectively (Table 1).

For the second altitude (1300-1500 m), the same results were obtained and there were significant differences among the aspects (P≤ 0.01%). The higher and lower values of 107.67 and 48.68 kg/ha were obtained for the north and south directions, respectively (Table 1).The results of ANOVA analysis for the third altitude (1500-1700 m) had a same trend. There were significant differences among the aspects (P≤ 0.01%). The higher and lower amounts of stored carbon with the average values of 108.98 and 78.53 kg/ha were obtained for the north and south directions, respectively (Table 1).

For the fourth altitude (1700-1900 m), the north and south directions with the average values of 112.56 and 83.19 kg/ha had higher and lower amounts of the stored carbon, respectively (Table 1). And finally, for the highest level of altitude (1900-2100 m), ANOVA analysis showed significant differences among the aspects for the amount of carbon sequestration (P≤ 0.01%). The higher and lower rates of the stored carbon with the average values of 118.68 and 66.06 were obtained for the north and south directions, respectively.

Table 1. The ANOVA analyses for stored carbon in the first altitude stratum (1100-1300 m.a.s.l) in four directions

Slop Aspect	1100-1300m	1300-1500m	1500-1700m	1700-1900m	1900-2100m	Total Means
North	101.55±9.63	107.67±6.64	108.89±6.41	112.56±8.06	118.68±2.29	109.87
South	39.13±4.14	48.68±4.36	78.53±13.88	83.19±7.03	66.06±5.33	63.12
East	91.75±7.59	68.51±9.03	87.57±9.52	92.98±4.23	88.08±7.44	85.78
West	80.74±3.56	75.85±14.78	91.24±9.64	97.87±4.97	94.20±5.67	87.98
F test	**	**	**	**	**	**
Total means	78.29	75.18	91.56	96.65	91.76	86.69

** Significant level (P≤ 0.01).

Discussion and Conclusion

The results suggest that the topographical factors (the altitude and slope directions) had significant effects on the carbon sequestration of *A. gossypinus* being in agreement with the views presented by Wei (2006), Rhoton *et al.,* (2006) and Norton *et al.,* (2003). In the present study area, the maximum and minimum amounts of carbon sequestration were achieved in the altitudes of 1900-2100 m and 1100-1300 m, respectively. Altitude is one of the most important physiographic parameters which will be able to change most site properties in a typical ecosystem. Due to the effects on the climatic parameters of a region such as temperature and precipitation, the altitude factor plays an effective and positive role in the quantitative increase of plant vegetation, and therefore helps to build up the carbon sequestration potential in the rangeland ecosystem (Azarnivand *et al.,* 2003). Moreover, the maximum amount of the total carbon sequestration in all 5 altitude layers was observed in the north direction while the minimum amount of the total carbon sequestration was recorded in the south direction. It seems that what contributed to the increase in the amount of the total carbon sequestration in the north slopes is related to the high density of the herbal species at the altitude caused by the contribution of northern slopes due to the lower sunlight absorption and the moisture retaining that leads to the vegetation growth in greater density. Evaporation and perspiration occurred less in the given slopes compared to the other directions. So, the 5th altitude class itself is another factor influencing the increase in the total carbon sequestration because of its altitude characteristic, topographic spot, impracticability and lack of cattle grazing. And in the south slopes, the opposite is true;

therefore, the total carbon sequestration in each altitude of the south slope in the study area was observed less in comparison with three other directions. In addition, Franzmeier *et al.,* (1969) in their investigation of carbon sequestration related to the slope aspect suggested that there is a greater amount of the sequestered organic carbon in the slopes standing toward the north in comparison to other directions which is in agreement with the results obtained from the research investigations conducted by Heidari *et al.,* (2010), Han *et al.,* (2010) and Chen *et al.,* (2006) in the study area. 1st altitude stratum (1100-1300 m.a.s.l), on the other hand, is the most vulnerable altitude stratum in terms of the areas having natural resources, especially rangelands and range plants. This is because this stratum is readily available for residential, gardening, agricultural and husbandry uses, and it is also quite possible to locate the ranges and the plant species therein. Thus, because of burning the farms, the 1st altitude stratum has the lowest vegetation density of the given species in proportion to the other strata, and since the amount of vegetation density is one of the indices of carbon extraction, the lower stratum revealed less carbon sequestration than that in other altitude strata. By the same token, there is greater erosion in the given stratum as the result of the undue interferences leading to the infertility of the soil and loss of herbal species or at least a decline in their concentrations.

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