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The Effect of Range Management on Soil Carbon Content in Degraded Soil

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Abstract: Degradation of soil and plant vegetation is a serious problem in grasslands at Central Antolian Region of Turkey. Soils and plant vegetation in this region are highly degraded due to uncontrolled heavy grazing. Measures should be taken to restore the degraded grasslands to effectively prevent desertification in this region. This study was conducted to evaluate the impacts of treatments; fertilized + planted + protected from grazing (A), Fertilized + protected from grazing (B), protected from grazing (C), and grazed (D) on soil organic carbon (SOC), inorganic carbon (IOC) and total carbon (TOC) content at four natural parcels between 2004-2008 in Sivas, Turkey. Results showed that the applications did not cause a significant difference in topsoil SOC, IOC and TOC values, but significant differences were observed in subsoil ($p < 0.001$). The highest TOC content was found in degraded grassland and the SOC value was found lower in planted, fertilized and protected parcel than open grazed parcel. Hence, the increasing of SOC in degreaded lands may take longer time than the expected time in arid climate.

Keywords: Grassland management, soil organic carbon, inorganic carbon, total carbon, desertification.

1. Introduction

The management of grassland is important for forage quality and soil organic carbon (SOC) storage. Grassland management techniques affect biomass production and also SOC (Conant et al., 2001). This management practices include fire, fertilizer, grazing, and clipping. The improvement of plant coverage in grassland reduces erosion and sedimentation, and improves water quality. SOC content is closely realted to plant qulity and soil coverage.

Land planted with perennial vegetation improves soil coverage and quality. Conversion of an area to grassland increases SOC (Gebhart et al., 1994; Lal et al., 1999). The content of SOC has been determined as a good quality indicator (Shukla et al. 2006). Lal et al. (1999) reported that conversion of an agricultural ecosystem to grassland increases SOC. Little information is available to quantitatively describe the effect of long-term management systems on SOC (Franzluebbers et al. 2000). The effect of chemical fertilizers on water use efficiency was significantly in grassland however, the fraction of belowground to total biomass decreased with the addition of chemical fertilizer (Li et al., 2011). In Mongolia grassland, a four-year study with several N application levels resulted that N application created no effect on above ground net primary productivity (Bai et al., 2010). However, nitrogen application enhanced plant growth and sustained restoration of degraded plant communities in Inner Mongalia steppe (Bai et al., 2010). The increase of water potential with N application in dry ecosystem enhances above ground biomass production and eventually C fixation to soil (Chen and Shi 2007). However, in native ecosystem more than above ground biomass below ground production accounts 60% of annual C originated from plants (Milchunas and Lauenroth 2001; Chen et al. 2006). Grazing changes species composition and decreases above ground net primary productivity (Zhou et al. 2006). Ogle et al. (2004) using a global dataset reported that improving grasslands in tropical areas can increase the SOC by 17%. On the other hand, poor management and overgrazing increase C losses (Garcia-Oliva et al., 2006; Elmore and Asner, 2006).

The effect of management systems on SOC content depends on climate, frequency of precipitation, and species composition. The study area had lower precipitation with poor plant coverage and moderate erosion. Therefore, the improvement of vegetative coverage and C movement to the soil are critical for soil and environmental quality. The objective of this study was to determine the effect of some management systems to restore degraded grasslands with measuring soil organic carbon (SOC), inorganic carbon (IOC) and total organic carbon (TOC) content in semi-arid Central Anatolia regions of Turkey. For this purpose, fertilizer application, plantation, conservation and their combinations were compared after five years of the study period.

2. Materials and Methods

This study was conducted at four natural grassland plots in Sivas region of Central Anatolia. The elevation at the study site is 1411m and mean annual precipitation is 306.4 mm. The mean annual temperature is 9.4^{o}C. The slopes range from 15% to 20%. The predominate vegetation species are Graminea and Fabaceae. The other vegetation types are steppe and meadow. In the study sites, natural grassland is mostly degraded due to heavy and early grazing.

The soil of the study area are moderately permeable, and has a low available water capacity, moderate water erosion hazard, moderate runoff, and a mean available rooting depth of 70 cm.

This study was conducted at four plots named A, B, C and D, each representing a different treatment. In treatment A, a mixture of 20% Agropyron cristatum, 40% Sanguisorba minor and % 40 Hedysarum pogonocarpum was sown in lines with 50 cm intervals oriented along the slope in April 2004. Fertilizer (20-20-0) (N-P-K) was applied to these parcels (0.25 Mgha^{-1}) during the planting and the plots was kept as ungrazed.

In treatment B; the plots were fenced to protect from grazing and 0.25 Mgha^{-1} composed fertilizer (20-20-0) was applied. No planting was performed at this plot.

In treatment C, there was a protection against to grazing without any fertilizer application.

In treatment D; the plots were allowed to grazing and the plots did not have any fertilizers. There was not any amenajman for grassland improvement in this plot. These plots were harvested at the same time in June 2005, 2006, 2007, and 2008. Soil samples were taken ten locations from each plot at 0-0.2 m and 0.2-0.4 m depth in June. Soil samples were stored in a plastic container until analysis, and pulverized samples were pased through a 2 mm sieve and stones and large plant roots or debris were removed. Then the soil samples were analyzed for soil organic carbon using wet oxidation of Walkley-Black procedure (Nelson & Sommers, 1982) and $CaCO_3$ content with a pressure calcimeter (Nelson, 1982). The grasses were harvested from 5-6 cm height and dried in an oven at 60^{o}C until a constant weight (Tosun & Altın, 1981). Canopy cover was determined by Quadrat Methods (Genckan, 1992).

The research was carried out in four grassland plots without replication. Plot sizes were 5 x 10 m with a uniform slope of 15%. Soil samples and plant properties were measured randomly selected ten different locations of each plot. Differences in soil and plant properties were analyzed statistically with one-way ANOVA and means were grouped with LSD test if the variation was significant at 0.05 probability.

3. Results and Discussion

The effects of different applications on the soil properties were evaluated at the end of the five years study periods (2004-2008). The descriptive statistics of the treatments for topsoil are given in Table 1. In the topsoil, the SOC, IOC and TOC values changed from 6.38 – 13.92, 2.16 – 7.08 and 9.50 – 18.90 g kg^{-1} respectively.

Table 1. *Descriptive statistics of some topsoil and grassland properties at the treatment plots*

Properties	Minimum	Maximum	Mean	SD	Varians	CV
SOC	6.38	13.92	9.33	1.99	3.96	21.33
IOC	2.16	7.08	4.38	1.40	1.95	31.96
TOC	9.50	18.90	13.72	2.27	5.18	16.55
CP	5.75	99.25	60.83	24.62	606.03	40.47
DGY	176.40	1727.60	730.87	431.23	185958.00	58.97

* SD: Standart deviation; CV: Coeficient of variation; SOC: Soil organic carbon (gkg^{-1}); IOC: Inorganic carbon(gkg^{-1}); TOC: Total organic carbon(gkg^{-1}); CP: Cover percentage (%); DGY: Dry grass yield ($kgha^{-1}$).

Table 2. *Descriptive statistics of some subsoil and grassland properties at the treatment plots*

Properties	Minimum	Maximum	Mean	SD	Varians	CV
SOC	4.52	13.23	8.80	2.04	4.15	23.18
IOC	2.16	8.88	4.51	1.55	2.40	34.37
TOC	8.96	18.99	13.30	2.19	4.80	16.47

* SD: Standart deviation; CV: Coeficient of variation; SOC: Soil organic carbon (gkg^{-1}); IOC: Inorganic carbon(gkg^{-1}); TOC: Total organic carbon(gkg^{-1}).

In generally, higher CV of variables was found in CP and DGY. Mulla and McBratney (2002) grouped CV-values nominally. According to their grouping, SOC, IOC and TOC exhibited medium variation in the topsoil (Table 1). The descriptive statistics of the treatments for subsoil are given in Table 2.

In the subsoil, the SOC, IOC and TOC values changed from 4.52 – 13.23, 2.16 – 8.88 and 8.96 – 18.99 g kg^{-1} respectively. According to Mulla and McBratney (2002) grouping, SOC, IOC and TOC exhibited medium variation in the subsoil (Table 2).

Differences in SOC, IOC and TOC values in different treatments were analyzed with one-way ANOVA and means were grouped with LSD test if the variation was significant. The applications did not cause any significant difference in topsoil SOC, IOC and TOC values (Table 3).

However, significant differences were observed in subsoil and were grouped with the help of LSD test (Table 4). Fertilizer application significantly increased SOC content in the subsoil. Interestingly open grazed plots (D) had high SOC content. The highest SOC occurred in B, D and A treatments, and the lowest SOC occurred in C treatment. In treatment D, the SOC content had the similarity with treatment A and B. A and B treatments were significantly affected by fertilizers and D trial was also in a same group without fertilization ($p<0.01$). Fertilization applications stimulated plant growth and resulted more organic residue and eventually had high SOC content. The open grazed plots without fertilizer showed high SOC in treatment D. The greater SOC content in the treatment D than C and A trials were attributed to organic matter addition by grazing animals in previously. These results suggest that a controlled grazing may be a good practice to maintain a nutrient levels and also SOC content in grassland soils. The term of overgrazing is a subjective parameter that varies depending on climate and soil properties. In addition, weeds enhance an agronomic degradation; however, it could not necessarily stimulate a C loss. Since, weeds could contribute considerable amounts of C to soil. In addition, some studies reported that no change in SOC loss between good and degraded grasslands (Koutika et al., 1997; Neill et al., 1997; Schuman et al., 1999). Degraded grasslands represented no change in SOC content which has been attributed to an increase in root biomass with a shift from native vegetation to grasslands management (Camargo et al., 1999; Schuman et al., 1999).

Table 3. *Effect of treatments on topsoil properties in the study area*

Treatments	SOC	IOC	TOC
A	8.78[a]	3.82[a]	12.59[a]
B	10.23[a]	3.86[a]	14.09[a]
C	8.61[a]	4.84[a]	13.44[a]
D	9.74[a]	5.03[a]	14.77[a]

* SOC: Soil organic carbon (gkg^{-1}); IOC: Inorganic carbon(gkg^{-1}); TOC: Total organic carbon(gkg^{-1}).

Table 4. *Effect of treatments on subsoil properties in the study area*

Treatments	SOC	IOC	TOC
A	8.10[bc]	3.56[b]	11.67[b]
B	10.28[a]	3.82[b]	14.09[ac]
C	7.27[b]	5.56[a]	12.82[bc]
D	9.54[ac]	5.09[a]	14.63[a]

* SOC: Soil organic carbon (gkg^{-1}); IOC: Inorganic carbon(gkg^{-1}); TOC: Total organic carbon(gkg^{-1}).

There was a strong link between SOC and IOC contents in the grassland. In IOC values of A and B, C and D trials were in the same group. Both of two groups had very important differences ($p < 0.001$). C and D treatments represented higher IOC values than A and B treatments. In A and B trials, fertilizer applications enhanced plant growth with more root production and a higher hydraulic conductivity. The more canopy coverage in A and B trials decreased the evaporation loses. The better soil hydraulic conditions in A and B trials may cause a decrease in IOC content.

In TOC values of A and C, B and C, B and D trials were in the same group. A and D trials had a different trend from each other. The biggest TOC values were observed in B, D, C and A respectively.

The SOC, IOC, and TOC contents of the different trials have close values in the topsoil and subsoil. However, in the A, C and D trials, the SOC values decreased with the increases of soil depth. Such as permanent pasture or forestland, the SOC content are mostly same in the topsoil and subsoil because of root activity and no-till application. The IOC contents of A and B parcels decreased with an increase of soil depth, but in C and D parcels, IOC increased with the soil depth.

More above ground biomass and water consumption by plants in A and B plots resulted moving of inorganic carbon towards to the upper layers. Indeed, the vegetative growth in the C and D plots is more limited due to limited plant water consumption, rainfall which caused to movement of IOC through the deeper layer. The TOC contents of the trials decreased in the order of A, C and D parcels and there is no difference in B parcel with increasing soil depth.

4. Conclusions

This study indicated that SOC content between protected and open grazed plots are significantly different. The SOC content are higher in open grazed plots than protected. The SOC of planted, fertilized and protected parcel (A trial) are also lower than open grazed parcel, but the highest SOC is observed in fertilized and protected trials. In the study, some properties of degraded grassland are different than the others. The IOC contents were greater in the only protected (C trial) and open grazed (D trial) plots where the vegetation is poor, but in planted, fertilized and protected (A trial) and fertilized and protected plot (B trial) were low. Generally, total C content is greeter in the in the open grazed plots and the lower values are in the planted, fertilized and protected plots. Because of the different characteristics and management systems of grassland soil carbon content may act as different in natural ecosystem. Therefore, more studies should be conducted on regional aspects to know the effect of management practices on soil carbon content throughout the world.

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