Evaluation of temperature sensitivity of soil organic matter decomposition in relation to rangeland management, element stoichiometry and soil depth

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Expanded Abstract

Introduction

Soils are considered as the largest carbon sink in terrestrial ecosystems. Rangelands are the largest terrestrial biomass in world, and contain about 30% of terrestrial carbon stocks. The temperature sensitivity of soil organic matter decomposition (expressed with Q_{10}) is widely used to show the response soil organic matter decomposition to temperature changes. Some biotic and abiotic factors such as land management, soil nutrient contents and stoichiometry as well as soil depth can alter Q_{10}. Since soil carbon content is association with organic matter from vegetation and root turnover, over gazing or destruction can reduces inputs organic matter and leads to surface erosion and increased emission of carbon dioxide. Therefore, sustainable grazing management is effective for protection of soil carbon. It has been determined that fraction of stable and recalcitrant organic matter increases with increasing soil depth. Therefore, studying the Q_{10} in relation to soil depth, especially in natural ecosystems, will improve our understanding of carbon dioxide efflux.
Stoichiometry (for example, carbon/ nitrogen ratio) has an important effect on soil organic matter decomposition by changing the relative availability of carbon and nitrogen to soil decomposer. However, knowledge on stoichiometric relationship between soil nutrition and its effect on the Q_{10} is still limited. The main aim of this study was to investigate Q_{10} in relation to rangeland ecosystem management (grazed, protected and destroyed) and stoichiometry of elements and soil depth. Also, changes in carbon, nitrogen and phosphorus in relation to the rangeland management and depth of soil were considered in this study.

Material & Methods

Three adjacent rangelands ecosystems, located in Fandoghlo of Namin, Ardebil province, with different management (grazed, protected and destroyed) were selected.
Soil samples (0-10, 10–20 and 20-30 cm depth layer) were randomly collected from three rangelands during the mid-growing period. Soil Samples were sieved (<2 mm) and placed in a refrigerator at 5ºC before incubation. Homogeneous soil samples (50 g) from all three rangeland ecosystems in three depths of 0-10, 10-20 and 20-30 cm of soil separately were incubated in half-liter Mason jars at three temperature levels (10, 20 and 30°C).
Control samples, with no soil, were incubated at the same time. An alkali trap containing 15 M ml NaOH 0.1 N was placed in each Mason jar to absorb the respired carbon dioxide. The moisture of each soil sample was adjusted to 60% water holding capacity. Soil moisture content was monitoring by weighing the jars every seven days. The carbon dioxide traps were removed 1, 4, 7, 14, 21 and 28 days after incubation and carbon dioxide emission was determined by the titration method. After determining the heterotrophic soil respiration, the Q_{10} was calculated as follows:

$$Q_{10} = R_{T_0+10}/R_{T_0}{}^{10/(T_0+10-T_0)}$$

where, R_{T_0} and R_{T_0+10} are the heterotrophic respiration at basic temperatures T_0 and $T_0 + 10$, respectively.
Analysis of variance were used separately to test the difference between the Q_{10} in three rangeland ecosystems (protected, grazed and degraded) at three depth levels, as well as changes in carbon, nitrogen and phosphorus

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nutrients in soil depths in three rangeland ecosystems. Regressions analysis were used to identify the trend of Q_{10} changes in related to carbon, nitrogen and phosphorus stoichiometry.

Discussion of Results

According to the results, the type of ecosystem had a significant effect on Q_{10} value. The highest and lowest Q_{10} with 1.21 and 0.87 value obtained from grazed and destroyed rangeland ecosystems, respectively. The value of Q_{10} in the protected rangeland was 0.97. Similar to this result, some studies have shown that the Q_{10} value in grazed rangeland was higher than in protected rangeland. These differences may contribute to differences in SOC quality or soil enzyme activity. The low Q_{10} found in grazed rangeland may be explained by the low labile carbon content of this ecosystem. The Q_{10} value was significantly higher in the bottom soil depth of grazed rangeland (1.373) and protected rangeland (1.149) compared to other depths. Generally, in this study, except degraded rangeland, the Q_{10} value increased with soil depth. The decreasing labile carbon content (carbon quality) with soil depth may be one of the contributors to the increased Q_{10} with depth. Similar to the present study, others have found that decreased carbon quality with increasing depth, may cause of decrease Q_{10} in the soil profile of forest and rangeland ecosystems. In the destroyed rangeland, a significant decrease in the organic carbon content of the soil due to the destruction of vegetation and erosion may decrease microbial population, thus leading to decrease of Q_{10} value.

In this study, the decreasing trend in Q_{10} value was observed with increasing carbon content in all three ecosystems. However, the relationship between Q_{10} and SOC was not significant in destroyed rangeland but was significant in protected and grazed rangeland.

The Q_{10} value in grazed rangeland decreased logarithmically with SOC. However, protected rangeland decreased linearly with SOC. Optimal incubation conditions in the lab can lead to an increase in labile carbon concentration. Hence, the high amount of organic carbon incubation releases high amount labile carbon content and thus decreases the Q_{10} value. The logarithmic and second-order polynomial model (U shaped) was the best fitted models for Q_{10} changes in association to soil nitrogen in grazed and protected rangelands, respectively. It seems that the decrease in Q_{10} with increasing nitrogen content is consistent with carbon quality. Nitrogen increase may lead to smaller C:N ratios (higher substrate quality) in soil, which consequently resulted in deceased Q_{10}.

The Q_{10} depicted a significant logarithmic decrease with increasing soil phosphorus content in both grazed and protected rangelands. The phosphorus, because of importance role of in cellular pathways, may cause increased soil microbial biomass carbon which probably induced efficiency of increasing carbon consumption, resulting in a decrease in the Q_{10} value. The Q_{10} was linear related to increasing the C:N ratio in grazed rangeland. This finding is also explained by carbon quality theory. Several studies have pointed to a positive relationship between the ratio of C:N and Q_{10}. in the protected rangeland. Q_{10} showed second-order polynomial (U shape) model with C:N ratios. Given the similar U shape model between Q_{10} with nitrogen and C:N ratios in this ecosystem, it can be realized the important effect of nitrogen on the carbon use efficiency (CUE) by microorganisms. In destroyed rangeland, the Q_{10} showed an exponential decrease with increasing C:N ratios. The variation pattern of Q_{10} in relation to the P:N ratio was similar to the C:N ratio. It seems that phosphorus availability in soils is also influenced by soil nitrogen changes. The power model was the best model fitted to data between Q_{10} changes and C:P ratio in destroyed rangeland, although this model did not reach statistical significance (P<0.05). Although studies on the stoichiometry P: N and C:P in soils are very limited, a study showed that the low C:P ratio leads to an increase carbon dioxide release per unit area. Thus, considering the principle of direct relationship between Q_{10} and carbon dioxide release per unit area.

Conclusions

This study showed that the management and conservation of rangeland ecosystems can be effective on the loss of carbon from the soil. It seems that increasing the quality of organic carbon in the protected rangeland has led to a decreases Q_{10} value. The low amount of organic matter due to loss of carbon during the degradation period may result in a decreased value of Q_{10} in the destroyed rangeland. In general, decreasing trend in Q_{10} value with increasing carbon, nitrogen and phosphorus content was observed in this study. This is consistent with q-theory model. The results obtained from nitrogen, carbon and phosphorus stoichiometry in this study indicated that nitrogen played a more important role in increasing the carbon use efficiency (CUE) and decrease Q_{10} which resulting in a decrease of greenhouse gas carbon dioxide emissions.

Keywords: carbon dioxide emissions, incubation, q-theory, rangeland.