Effects of Grassland Patches on the Composition and Stability of Soil Aggregates in the Qinghai-Tibet Plateau

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Abstract. Grassland patchiness was an important process in the succession of grassland degradation. The changings of soil aggregates were affected by grassland patches, which in turn affect soil organic carbon mineralization. In this study, the soil aggregates were divided into three particle sizes: macroaggregates (2-0.25mm), microaggregates (0.25-0.053mm) and clay-silt aggregates (<0.053mm) through the wet sieve method. The indoor culture method measured the cumulative mineralization of soil organic carbon. The study analyzed the changes of soil aggregates in the grassland patches of the Qinghai-Tibet Plateau, and the influences of soil aggregates on the soil organic carbon mineralization. The results of the study showed that grassland patches caused significant differences in soil aggregates. Compared with native vegetation, single plant patches and bare area formed by degradation would reduce the stabilities of aggregates and increased the amount of organic carbon mineralization. Soil aggregates of grassland patches have a significant effect on the cumulative mineralization of organic carbon. Therefore, study of changes in soil aggregates and the impacts of aggregates on organic carbon mineralization would help to accurately understand the future carbon cycle of terrestrial ecosystems and climate changes.

1. Introduction

Soil aggregate was an important indicator of soil structure, and soil stability was closely related to the number and characteristics of soil aggregates[1]. Aggregates of different particle sizes have different performance in improving soil fertility conditions and reducing erodibility[2]. The stability of soil aggregates is a direct manifestation of changes in soil quality and the succession of ecosystem degradation. Studies have shown that vegetation types and characteristics are important factors affecting the spatial distribution and stability of aggregates. The formation of soil aggregates is largely affected by the combined effects of the vegetation structures, roots, and litters of above-ground vegetations of different plant communities. Soil aggregation mainly composed of fresh organic matter cemented into macroaggregates, and then coarse particles in the aggregates organic matters were decomposed into microaggregates by microorganisms, thereby changing the state of the aggregates in the soil, which is a dynamic change process.

The changes of grassland soil carbon release are influenced by vegetation[3]. The phenomenon of grassland patching in the Qinghai-Tibet Plateau is common, which is a long-term and very important process in the degeneration and succession of natural grassland. The aggregation and distribution of grassland patches will change the local materials addition, elements migration and microbial activities in the soil, which will strongly affect the soil structures and properties, resulting in more obvious spatial
heterogeneity. At the same time, the effects of grassland patches on soil heterogeneity restricts the circulation of soil nutrients, which has attracted widespread attentions. However, the current understanding of the changes of soil aggregates in grassland patches is still insufficient, and the effect of aggregates in patches on organic carbon mineralization has not been reported. Therefore, clarifying the relationships among grassland patches, soil aggregates and soil organic carbon mineralization are of great significance to the understanding of terrestrial ecosystems and global climate change.

2. Study area and data
This study was conducted on the alpine grassland of the Qinghai-Tibet Plateau, 10km west of Maqu County, Gannan Tibetan Autonomous Prefecture. The geographical coordinates are 33°50′-36°15′N,101°05′-102°20′E. The average altitude is about 3500m, which belongs to the obvious plateau climate zone and is a typical cold and humid climate zone. The soil type is subalpine meadow soil.

The community patches in the experimental study area are mainly native vegetation (CK), Potentilla fruticosa, Polygonum viviparum, Ligularia virgaurea. (Table 1)

Table 1. Basic situation of the study plots

| Patches                      | Underground biomass (g m-2) | Aboveground biomass (g m-2) |
|------------------------------|-----------------------------|-----------------------------|
| native vegetation (CK)       | 2841.68±498.94 ab          | 401.80±13.61 b              |
| Potentilla fruticosa (PF)    | 3422.30±214.85 a           | 10085.97±469.62 a           |
| Polygonum viviparum (PV)    | 2394.29±379.01 b           | 650.36±159.00 b             |
| Ligularia virgaurea (LV)     | 2312.15±499.89 b           | 465.53±26.65 b              |
| bare area (BA)               | 563.36±31.36 c             |                             |

3. Methods
(1) The calculation formula for the content of each particle size of soil aggregates is as follows:[4]:

\[ w_i = \frac{w_0}{100} \times 100\% \]  \hspace{1cm} (1)

Where Wi is the ratio of the weight of i-size aggregates to the dry weight of the soil sample, and W0 is the weight of i-size soil aggregates.

(2) Formulas for the mean weight diameter (MWD) and geometric mean diameter (GMD) of soil aggregates:[5, 6]:

\[ \text{MWD} = \frac{\sum_{i=1}^{n} x_i w_i}{\sum_{i=1}^{n} w_i} \]  \hspace{1cm} (2)

\[ \text{GMD} = \exp \left[ \frac{\sum_{i=1}^{n} w_i \ln x_i}{\sum_{i=1}^{n} w_i} \right] \]  \hspace{1cm} (3)

Where Xi is the average diameter of aggregates in the i particle size range, and Wi is the ratio of the weight of i-size aggregates to the dry weight of the soil sample.

(3) The calculation formula of the fractal dimension (D) of soil aggregates is as follows:

\[ \frac{M(r<x_i)}{M_T} = \left( \frac{x_i}{x_{\text{max}}} \right)^{3-D} \]  \hspace{1cm} (4)

Where: Xi is the average diameter of aggregates with a particle size of i, M (r<x_i) is the weight of the aggregates with a particle size smaller than Xi, MT is the total weight of the aggregates, and Xmax is the maximum particle size of the aggregates.

Using Excel 2010 and IBM Statistics SPSS 20.0 software to perform analysis. SigmaPlot 14.0 was used to map the analyzed data.

4. Results

4.1 Percentage contents and stability indexes of aggregates of various particle sizes in grassland patches soil
The study analyzed the percentage of soil aggregates in grassland patches (Figure 1). It can be seen that
percentage of macroaggregates were the largest in grassland patches, accounting for 55.31% to 74.01% of the total aggregates, while the contents of clay-silt aggregates were the least, accounting for 3.43% to 15.80% of the total aggregates. For the percentage of macroaggregates, native vegetation patches were the highest. Compared to native vegetation, the percentage of macroaggregates other patches decreased by 0.82%~18.70%. The percentage of microaggregates in bare area was the highest, at 28.89%, and *Ligularia virgaurea*, *Potentilla fruticosa*, native vegetation and *Polygonum viviparum* patches decreased sequentially (Figure 1).

We found that the MWD value range of the aggregates in the grassland patches was 0.67~0.87, the GMD value range was 0.63~0.82, and the D value range was 2.14~2.56. The MWD and GMD values of the bare area patches were significantly lower than the other patches (*P*<0.05). Among the other patches, the D value of the *Polygonum viviparum* patch was the highest, and the D value of *Ligularia virgaurea*, *Potentilla fruticosa* and native vegetation patches decreased in turn. This indicated that grassland patches had an impact on the stability of aggregates, and the formation of grassland patches reduced the stability of aggregates (Table 2).

![Figure 1](image.png)

**Figure 1.** The percentages of soil aggregates of each particle size in grassland patches on the Qinghai-Tibet Plateau

| Patches | Average weight diameter (MWD) | Geometric mean diameter (GMD) | Fractal dimension (D) |
|---------|--------------------------------|-------------------------------|----------------------|
| CK      | 0.87±0.003 a                  | 0.82±0.005 a                  | 2.14±0.05 b         |
| PF      | 0.86±0.01 a                   | 0.81±0.01 a                   | 2.15±0.05 b         |
| PV      | 0.85±0.01 a                   | 0.80±0.004 a                  | 2.22±0.03 b         |
| LV      | 0.83±0.01 a                   | 0.79±0.009 a                  | 2.17±0.06 b         |
| BA      | 0.67±0.05 b                   | 0.63±0.03 b                   | 2.56±0.02 a         |

4.2 Organic carbon and total nitrogen content of soil aggregates in grassland patches

The particle size of the aggregates decreased (Figure 2), the organic carbon contents of the aggregates generally showed a "V" shaped trend (Figure 2a). The organic carbon content in the macroaggregates of native vegetation, *Potentilla fruticosa* and *Polygonum viviparum* patches were significantly higher than that of *Ligularia virgaurea* and bare area, and the organic carbon content in the macroaggregates of *Ligularia virgaurea* was significantly higher than that in bare area (*P*<0.05). The organic carbon content in the clay-silt aggregates of native vegetation was the highest, which was 126.61 g kg⁻¹; the organic...
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carbon content of the clay-silt aggregates of bare land patch was the lowest which was 52.92 g kg\(^{-1}\) (Figure 2a).

The total nitrogen content of soil in macroaggregates of native vegetation was significantly higher than that of Potentilla fruticosa, Ligularia virgaurea and bare area (\(P<0.05\)). The total nitrogen content in the clay-silt aggregates of the native vegetation, Potentilla fruticosa and Polygonum viviparum patches were significantly higher than that of Ligularia virgaurea and bare patches (\(P<0.05\), Figure 2b).

\[ \text{Figure 2. The content of organic carbon and total nitrogen in soil aggregates of various particle sizes in grassland patches on the Qinghai-Tibet Plateau} \]

4.3 Cumulative mineralization of soil organic carbon in grassland patches

At the beginning of the mineralization, the organic carbon mineralization increased rapidly, and gradually became flat (Figure 3a). The results also showed that organic carbon mineralization/soc in grassland patches was significantly different in each patch (\(P<0.05\), Figure 3b). After 359 days of mineralization experiments, the organic carbon mineralization/soc varied from 8.11 to 12.38 g kg\(^{-1}\)soc (Figure 3b). Cumulative mineralization/soc of Ligularia virgaurea and bare area were significantly higher than that of other patches (\(P<0.05\)), and there was no significant difference among Potentilla fruticosa, Ligularia virgaurea and native vegetation (Figure 3b).

\[ \text{Figure 3. Cumulative mineralization of soil organic carbon in grassland patches} \]

5. Conclusion and Discussion

The contents and distributions of soil aggregates determine the stabilities of soil aggregates and protect
soil organic carbon from microbes. The formations of different grassland patches caused significant differences in soil aggregates. The patching of grassland in degraded succession would reduce the contents of soil macroaggregates and the stabilities of aggregates. This study showed that the percentages of macroaggregates in the patches of native vegetation were highest, the percentage of microaggregates and clay-silt aggregates were lower than macroaggregates. In the patches of native vegetation, aggregates had higher stability than other patches. The percentages of macroaggregates in bare area were lower than other patches, and the percentages of microaggregates and clay-silt aggregates were higher than other patches. In patches of bare area, the percentages of aggregates were higher, and the stabilities of the aggregates were lower. Some studies have shown that different vegetation coverage lead to differences of organic matter entering the soil, and influence soil properties. The glue of these organic matter and the decomposition and transformation of microorganisms in the soil were considered as the main driving factors for the formations and transformations of soil aggregates. This may be one of the reasons for the significant differences in the contents, distributions and stabilities of soil aggregates in different grassland patches.

Our results also showed that the contents of macroaggregates were negatively correlated with cumulative mineralization/soc. Macroaggregates have a physical protective effect on soil organic carbon. The bare area was not covered by vegetation, and there were fewer macroaggregates that can be glued, thus, the value of organic carbon mineralization/soc in bare area was higher.

References
[1] Bird, S B., Bird, SB., Herrick, JE., Wander, MM., Murray, L 2007 Geoderma. 140 106-118.
[2] Paul, B K., et al 2013 Agriculture Ecosystems & Environment 164 14-22.
[3] Han, Y., Zhang, Z., Wang, C., Wang, CH.,Wang, Jiang, FH., Xia, JY 2012 Journal of Plant Ecology 5 219-228.
[4] Beare, M H., Hendrix, P F., Coleman, D C 1994 Soil Science Society of America Journal 58 777-786.
[5] Dexter, A R 1988 Soil & Tillage Research 11 199-238.
[6] Yang, X M.,Wander, M M 1998 Soil & Tillage Research 49 173-183.