Landscape Position Effects on Amidohydrolase Activities within Soil Aggregates

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Abstract

Distribution pattern of enzyme activities in soil aggregates as affected by landscape position is not well understood. This study was carried out to investigate the effects of landscape position on the distribution of amidohydrolase activities within soil aggregates. Soil samples were collected from different landscape positions (summit, backslope and toeslope) in central Iran. Soil organic C (OC) content and amidohydrolase (urease, L-glutaminase and L-asparaginase) activities were measured in five aggregate classes (4–2, 2–1, 1–0.5, 0.5–0.25 and 0.25–0.05 mm). The contribution of each aggregate to total OC and soil enzyme activities was calculated based on the aggregate mass fraction. The highest and lowest macroaggregates (4–0.25 mm) to microaggregate (0.25–0.05 mm) proportion were observed in the summit (1.67%) and backslope (0.85%), respectively. The lowest enzyme activities and OC content were observed in the backslope. Amidohydrolase activities and OC content decreased as the size of aggregates decreased. However, microaggregate had a major contribution to the total aggregate OC content and amidohydrolase activities along the landscape. It was more pronounced in the backslope, which was more susceptible to soil erosion. Our findings revealed that landscape position not only influenced the total soil enzyme activity, but also modifies the distribution of the enzyme molecules in the soil aggregates.

Keywords

Amidohydrolase activities; Aggregate fraction; Landscape position

1. Introduction

Topography is one of the five fundamental elements of the soil–forming factor theory and is central to the catena concept for soil development [1]. Topography influences local and regional climate by changing the pattern of precipitation and temperature, solar radiation and relative humidity. Microclimate variations with altitude influ-
ence the type and composition of vegetation species, weathering rates and leaching intensity, resulting in feedback on soil properties and soil processes [2]. Khalili–Rad et al. [3] demonstrated that potentially mineralizable N, microbial biomass N and L–glutaminase activity were greater in toeslope position. The distribution pattern of L–glutaminase among the slope positions was similar to that of soil microbial respiration. Nahidan et al. [4] concluded that topography controls the distribution of urease, L–glutaminase and L–asparaginase activities through its effects on soil properties such as soil moisture and temperature levels, clay content, soil organic carbon, nitrogen concentrations, and vegetation cover.

One area of interest to examine soil microbial habitats is in the context of soil aggregates. Soil aggregates are mediated by soil organic matter, biota, ionic bridging, clay, and carbonates [5]. Soil fractionation studies have revealed an uneven distribution of enzyme activity in the soil matrix. Micro–scale investigations of enzymes in the soil should be utilized to strengthen our understanding about the microbial turnover of soil nutrients [6]. Effects of topography on aggregate size distribution have previously been recognized [7, 8]. Since there is a close relationship between soil physical structure and microbial life [9, 10], any alterations in soil aggregation as a result of various factors such as topography may influence the microorganisms and their activity in soil. We hypothesized that distribution pattern of enzyme activities within aggregate size classes influenced by landscape position. In this study, we considered amidohydrolase activities [urease (EC 3.5.1.5), L–glutaminase (EC 3.5.1.2) and L–asparaginase (EC 3.5.1.1)] as soil enzymes participating in the soil N mineralization process. The enzymes are central regulators of N cycle in microbial cells and produce inorganic N during the decomposition of aliphatic N compounds in soil organic matter [11]. To our knowledge, the distribution pattern of amidohydrolase activities within soil aggregate size classes along a landscape has not yet been reported. Such studies are important for identifying microbial habitats with greater biochemical activity and sustaining soil management practices. Therefore the objectives of this study were to investigate (i) the influence of landscape position on soil aggregate size distribution and (ii) the effects of landscape position on the soil amidohydrolase activities within different aggregate size fractions.

2. Materials and Methods

The landscapes studied are located at Fereydan area, western of Isfahan province, central Iran (50º 11′E, 32º 45′N). The mean annual precipitation and temperature are 600 mm and 5º C, respectively. The landscape studied was 100 m long and 40 m wide, and elevation ranged from 2583 to 2630 m. Soil samples were collected along the landscapes based on the landform features including summit, backslope and toeslope. At each landscape position, three equally spaced points were selected, at a distance of 10 m. In each point, ten soil cores of 0–10 cm depth were taken within a 2 m radius and composited. The soil samples were sieved through a 4 mm mesh for aggregate size fractionation.

Five size of soil aggregates (4–2, 2–1, 1–0.5, 0.5–0.25 and 0.25–0.05 mm) were separated by wet sieving method [12]. The soil aggregates were stored at 4°C to measure LGL activity within 2 weeks. A sub-sample of collected aggregates was air-dried to determine general analysis and another one was oven-dried (105 ºC, 24h) to determine the proportion of aggregate of the whole soil mass. Organic C (OC) content, urease (URS), L–glutaminase (LGL) and L–asparaginase (LAS) activities were determined in bulk soils (non–fractionated soils) as well as separated aggregates. The OC was assayed by wet digestion procedure [13]. The URS, LGL and LAS were measured according to the protocols described by Tabatabai [15].

The relative contribution of each aggregate size fraction (R) to total OC content and the enzyme activities (%) was calculated as follows:

\[ R = \frac{(A_i \times C_i)}{B} \]

where \( A_i \) is absolute value of OC (g kg\(^{-1}\)) or enzyme activities (mg NH\(_4\)–N kg\(^{-1}\) h\(^{-1}\)) in each aggregate size (i), \( C_i \) is the contribution of each aggregate to whole soil mass (%) and \( B \) is the values of measured parameters in bulk soil.

A randomized complete block design was used with three replicates. Mean comparisons (LSD, \( P< 0.05 \)) were accomplished by SAS software.
3. Result

3.1. Distribution of aggregate fractions

The proportion of largest macroaggregates (4–2 mm) represented the smallest fraction while microaggregate (0.25–0.05 mm) comprised the largest fraction in all soils along the landscape. Macroaggregates (4–0.25 mm) consisted 41.7% of the summit soil while the percentage decreased to 23.4 and 34.8% in the backslope and toeslope, respectively. On the other hand, the effect of landscape position on aggregate size distribution was more pronounced for 4–2 mm fraction. The proportion of 4–2 mm fraction of summit was 4.8% which is 6.86 and 2.67 times greater than that of backslope and toeslope, respectively (Table 1).

Table 1. Aggregate size distribution (%) in soils from different landscape positions

<table>
<thead>
<tr>
<th>Landscape position</th>
<th>Aggregate size (mm)</th>
<th>4–2</th>
<th>2–1</th>
<th>1–0.5</th>
<th>0.5–0.25</th>
<th>0.25–0.05</th>
</tr>
</thead>
<tbody>
<tr>
<td>Su</td>
<td></td>
<td>4.8aC</td>
<td>11.9bA</td>
<td>11.9bA</td>
<td>13.1bB</td>
<td>25.0bA</td>
</tr>
<tr>
<td>Bs</td>
<td></td>
<td>0.7cE</td>
<td>3.1cD</td>
<td>8.6bC</td>
<td>11.0cB</td>
<td>27.5aA</td>
</tr>
<tr>
<td>Ts</td>
<td></td>
<td>1.8bD</td>
<td>6.7bC</td>
<td>12.3aB</td>
<td>14.0aB</td>
<td>22.6aB</td>
</tr>
</tbody>
</table>

Su, Summit; Bs, Backslope; Ts, Toeslope. Values followed by different lowercase letters in a column and within each site are significantly different (LSD, \( P < 0.05 \)). Values followed by different uppercase letters in a row are significantly different (LSD, \( P < 0.05 \)).

3.2. OC of aggregate fractions

Organic C values in the soil aggregates along the landscape varied from 10.2 to 22.4 g kg\(^{-1}\) (Figure 1). The OC in the summit decreased as the size of aggregates decreased. In the backslope and toeslope positions, the highest and lowest OC values were observed in the 2–1 and 0.25–0.05 mm fractions, respectively. The aggregate fractions of backslope generally possessed lower OC value than other positions (Figure 1). When OC in soil aggregates was weighed to the proportion of aggregate fractions in each soil, microaggregate (0.25–0.05 mm) of all landscape positions exhibited a greater contribution, while 4–2 mm fraction made the lowest contribution to OC content than other fractions (Figure 2).

Figure 1. Organic C of aggregate fractions from different landscape positions. Su: Summit, Bs: Backslope and Ts: Toeslope. Means with different letters within each landscape position are significantly different (LSD, \( P < 0.05 \)).

Figure 2. Relative contribution of aggregate fractions to total organic C (%) of different landscape positions. Su: Summit, Bs: Backslope and Ts: Toeslope. Means with different letters within each landscape position are significantly different (LSD, \( P < 0.05 \)).
3.4. Amidohydrolase activities of aggregate fractions

Aggregate URS activity along the landscape ranged from 19.9 to 64.8 mg NH$_4$+–N kg$^{-1}$ h$^{-1}$ (Figure 3A). The URS activity decreased as the size of aggregates decreased. The activity of LGL ranged from 27.8 to 89.5 mg NH$_4$+–N kg$^{-1}$ h$^{-1}$ (Figure 3B), while the LAS activity varied from 1.97 to 19.83 mg NH$_4$+–N kg$^{-1}$ h$^{-1}$ (Figure 3C). Macroaggregates exhibited higher values in terms of LGL and LAS activities than microaggregate. The lowest amidohydrolase activities were generally observed in aggregate fractions of the backslope (Figure 3).

Relative contribution of aggregate fractions to the total URS, LGL and LAS activities of different landscape positions are shown in Figure 4A–C. The aggregate of 0.25–0.05 mm of all soils along the landscape had a greater contribution to soil URS, LGL and LAS activities than other fractions (Figure 4A–C). In contrast, 4–2 mm fraction contributed a minor proportion to the total soil amidohydrolase activities of different landscape positions.

Figure 3. Urease, L–glutaminase and L–asparaginase activity of aggregate fractions from different landscape positions (A, B and C). Su: Summit, Bs: Backslope and Ts: Toeslope. Means with different letters within each landscape position are significantly different (LSD, $P < 0.05$).

Figure 4. Relative contribution of aggregate fractions to total Urease, L–glutaminase and L–asparaginase activity (%) of different landscape positions (A, B and C). Su: Summit, Bs: Backslope and Ts: Toeslope. Means with different letters within each landscape position are significantly different (LSD, $P < 0.05$).
4. Discussion

Soil biochemical properties particularly soil enzyme activities, are sensitive to small changes in soil conditions, and thereby give accurate information on soil quality because the major part of organic matter and nutrient transformations in soil are microbially mediated [14]. In our study, amidohydrolase activities, the essential enzymes for N mineralization, varied considerably among the landscape positions (Figure 3). The trends observed for the amidohydrolase activities were consistent with the pattern of OC values. High levels of OC can provide available C and energy for microbial growth and therefore, increase enzyme production. Besides, soil humus provides more adsorption capacity for extracellular enzymes to be protected against denaturation [15].

Water stable aggregate fractions varied among landscape positions (Table 1). Microaggregates (0.25–0.05 mm) were generally the most predominant fraction among the soils along the landscapes studied. However, summit exhibited a greater proportion of macroaggregates (4–0.25 mm) to microaggregate (0.25–0.05 mm) compared to other landscape positions, that can be attributed to the higher organic matter content in the position. Several studies have shown that Organic C was the major binding material and had an improving effect on the stability and composition of water stable aggregates [12, 16]. Pierson and Mulla [7] demonstrated that variation in aggregate stability as affected by topography could be modeled in terms of organic C content and elevation. They showed that other properties such as amorphous Fe and water or clay content were only weakly correlated to aggregate stability.

The OC concentration in soil aggregates generally increased with increasing the size of aggregates (Figure 1). Our result is consistent with previous works suggesting that organic matter was increased with increasing the size of water stable aggregates [12, 17]. This result support the concept of aggregate hierarchy model according to which microaggregates are bound together by young organic matter into larger aggregates. As a consequence, OC values would increase with increasing the size of aggregates because larger aggregates are composed of smaller aggregates plus organic binding agents [18].

The activities of amidohydrolase in all soils along the landscapes were greatest in large macroaggregates (generally 4–2 mm) and decreased into microaggregate (0.25–0.05 mm), following a decrease of OC content (Figure 1 and 3). The findings corroborate other studies suggested that macroaggregates provide more favorable conditions for soil microbial biomass and enzyme activities [19, 20]. Spatial isolation of substrate among aggregate size fractions as well as heterogeneous distribution of microorganisms may contribute to the specific location of enzymes in the soil. Moreover, extracellular enzymes may accumulate at sites of preferential adsorption as a result of their surface active properties [21]. The high amidohydrolase activities and OC content of large macroaggregates indicated that these enzymes are mainly bound to and stabilized by organic matter [20, 21].

The contribution of aggregate fractions to total OC content and amidohydrolase activities was somehow similar to the distribution pattern of aggregate size classes (Table 1) along the landscape. In general, 4–2 mm fraction did not contribute considerably to total OC content and soil amidohydrolase activities, in spite of its higher OC and activities of the enzymes (Figure 2 and 4), because in terms of its mass fraction, this is a small component of the soils of landscape studied (Table 1). Conversely, microaggregate (0.25–0.05 mm) had a major contribution to the total aggregate OC content and amidohydrolase activities along the landscape. It was more pronounced in backslope position where its soils had a lower aggregation than other positions. The OC content was significantly lower in the backslope when compared to that of other positions. This suggests that soil erosion processes may have reduced the organic matter and inhibited the formation of larger and much stable aggregate fractions, especially in soils at the backslope position. It may be caused OC sequestration or extracellular enzyme accumulation in smaller aggregates than larger size classes.

In conclusion, landscape position as an important topographic factor, influenced not only the total soil enzyme activity, but also modifies the distribution of the enzyme molecules in the soil aggregates. Amidohydrolase activities decreased as the size of aggregates decreased. Considering the mass fraction of each aggregate, the proportional distribution of amidohydrolase activities generally skewed towards microaggregates. It was more pronounced in backslope position, which was more susceptible to soil erosion. Practical management strategies regarding to reduce soil biological pools loss is necessary along the landscape.

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References

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