Changes in Carbon and Nitrogen Stoichiometric Characteristics During Restoration of Degraded Vegetation in Horqin Sandy Land (Postprint)

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Abstract

To investigate the changes in carbon and nitrogen stoichiometric characteristics during the restoration of degraded vegetation in sandy land, vegetation surveys were conducted on mobile, semi-fixed, and fixed dunes as well as grasslands in mid-August of 2011, 2013, and 2015, and the carbon and nitrogen stoichiometric characteristics of the vegetation-soil system were measured. The results showed that: (1) With the restoration of degraded vegetation in sandy land, the C and N contents and C/N ratios of aboveground plants, litter, and roots fluctuated, while the C and N contents and C/N ratio of soil (0–10 cm) increased significantly ($P < 0.05$). (2) The C and N contents and C/N ratios of aboveground plants, litter, roots, and soil on the four habitats of sandy land showed significant interannual variations ($P < 0.05$). (3) During the restoration of degraded vegetation in sandy land, the C/N ratios of aboveground plants, litter, and soil exhibited a positive linear relationship with species richness ($P < 0.01$). During the restoration of degraded vegetation in sandy land, the succession of dominant plants led to changes in the C and N stoichiometric characteristics of the vegetation-soil system; the nitrogen use efficiency of plants also gradually increased during the vegetation restoration process, while increased enclosure duration could promote N accumulation in sandy soil.

Full Text

Changes of Carbon and Nitrogen Stoichiometry in the Restoration Process of Degraded Vegetation in Horqin Sandy Land

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Abstract: This study investigated the carbon and nitrogen stoichiometric characteristics of plant-soil systems along a restoration sequence of degraded vegetation in Horqin Sandy Land, Inner Mongolia, China. The research aimed to define the patterns of carbon-nitrogen stoichiometry during vegetation restoration and quantify relationships between C/N ratios and species richness, providing a theoretical foundation for sustainable management of sandy grasslands. A total of 24 plots (20 m × 20 m) were established across four habitats (mobile dune, semi-fixed dune, fixed dune, and grassland), with six replicate plots per habitat. Three 1 m × 1 m quadrats were sampled in each plot during mid-August of 2011, 2013, and 2015. Plant and soil carbon and nitrogen contents were analyzed using a Costech Elemental Combustion System 4010 (Italy). The results showed: (1) With vegetation restoration, the carbon and nitrogen contents and C/N ratios of aboveground plant, litter, and root showed fluctuating trends, while soil carbon, nitrogen content, and C/N ratio (0–10 cm) increased significantly ($P < 0.05$). The nitrogen content of aboveground plants in mobile dunes was highest, resulting in significantly lower C/N ratios compared to other habitats. Conversely, litter and root nitrogen contents in semi-fixed dunes were relatively lower, leading to higher C/N ratios. (2) From 2011 to 2015, the average carbon content of aboveground plants changed little, while nitrogen content increased significantly ($P < 0.01$). Litter carbon and nitrogen contents and C/N ratios fluctuated smoothly, with no significant interannual differences for roots. Soil carbon content and C/N ratio changed undulately, but nitrogen content increased significantly ($P < 0.01$). (3) The C/N ratios of aboveground plant, litter, and soil showed positive linear relationships with species richness during vegetation restoration ($P < 0.01$). In conclusion, vegetation succession during restoration drives changes in carbon-nitrogen stoichiometry of plant-soil systems, with nitrogen use efficiency increasing as degraded vegetation recovers. Extended fencing duration promotes soil nitrogen accumulation in sandy lands.

Keywords: C and N contents; C/N ratios; restoration of degraded vegetation; restoration ages; Horqin Sandy Land

1 Introduction

The study area is located in Horqin Sandy Land (42°55 –42°57 N, 120°40 – 120°43 E) at an elevation of 360 m. The region has a temperate semi-arid climate with a mean annual temperature of 6.4°C, ≥ 10°C accumulated temperature of 3000°C, and a 150-day growing season. Annual precipitation averages 360 mm, concentrated in 70–80% of the period from June to August,

while annual evaporation reaches 1972.8 mm. The vegetation community consists of Artemisia halodendron, Corispermum macrocarpum, Artemisia scoparia, Artemisia frigida, and Cleistogenes squarrosa. Soil samples were collected at four depths: 0–10 cm, 10–20 cm, 20–40 cm, and 40–60 cm. Data analysis was performed using Excel 2016, Origin 8.0, and SPSS 19.0.

2 Methods

2.1 Experimental Design and Sampling

Four habitats representing a restoration gradient were selected: mobile dune (dominated by Artemisia halodendron and Corispermum macrocarpum), semi-fixed dune (Artemisia scoparia and Artemisia frigida), fixed dune (Cleistogenes squarrosa), and grassland. Twenty-four 20 m × 20 m plots were established, with six replicates per habitat and distances between plots ranging from 0.5 to 8 km. In each plot, three 1 m × 1 m quadrats were randomly selected for plant and soil sampling during mid-August of 2011, 2013, and 2015.

2.2 Sample Analysis

Plant samples were separated into aboveground, root, and litter components. Soil samples (0–10 cm) were collected from each quadrat. All samples were analyzed for carbon and nitrogen content using a Costech Elemental Combustion System 4010 (Italy). Statistical significance was tested at $P < 0.05$ and $P < 0.01$ levels.

3 Results

3.1 Changes in Plant-Soil C and N Stoichiometry

During vegetation restoration, the carbon and nitrogen contents and C/N ratios of aboveground plants, litter, and roots exhibited fluctuating patterns across habitats [Figure 1: see original paper]. The nitrogen content of aboveground plants in mobile dunes was significantly higher than in other habitats, resulting in lower C/N ratios [Figure 3: see original paper]. Conversely, litter and root nitrogen contents in semi-fixed dunes were relatively lower, leading to higher C/N ratios in these components [Figure 4: see original paper].

Soil carbon, nitrogen content, and C/N ratio (0–10 cm) increased significantly with restoration ($P < 0.05$) [FIGURE:9, FIGURE:10]. From 2011 to 2015, the average carbon content of aboveground plants showed little change, while nitrogen content increased significantly ($P < 0.01$). Litter C, N, and C/N fluctuated smoothly, whereas root parameters showed no significant interannual variation. Soil carbon content and C/N ratio changed undulately, but nitrogen content increased significantly ($P < 0.01$) [Figure 5: see original paper].

3.2 Relationship Between C/N Ratios and Species Richness

The C/N ratios of aboveground plant, litter, and soil showed significant positive linear relationships with species richness during vegetation restoration ($P < 0.01$) [Figure 11: see original paper]. This indicates that as plant communities become more diverse during restoration, the stoichiometric balance of carbon and nitrogen becomes more optimized.

4 Discussion

Vegetation succession in the restoration process leads to significant changes in plant-soil carbon-nitrogen stoichiometry. The increase in species richness promotes more efficient nitrogen utilization, as evidenced by the positive correlation between C/N ratios and species diversity. Extended fencing duration significantly promotes soil nitrogen accumulation in sandy lands, suggesting that protection from disturbance is crucial for nutrient recovery.

The differential responses among habitats reflect varying restoration stages and plant functional types. Mobile dunes, with early successional species, showed higher plant nitrogen content, while semi-fixed dunes exhibited higher C/N ratios in litter and roots, indicating slower decomposition rates and nitrogen cycling. The overall increase in soil nitrogen content across all habitats demonstrates the effectiveness of natural restoration processes in improving soil fertility.

These findings provide a theoretical basis for understanding ecosystem functioning during vegetation restoration and support the implementation of long-term protection measures for sustainable management of degraded sandy grasslands.

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Note: Figure translations are in progress. See original paper for figures.