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Effectiveness of shrub planting and grazing exclusion on degraded sandy grassland restoration in Horqin sandy land in Inner Mongolia

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ABSTRACT

Effective methods of restoring lands stressed by desertification and sand movement are needed. The stabilization of sand dunes with shrub planting with the help of straw checkerboard (PCS) and grazing exclusion was evaluated in degraded sandy grasslands in Horqin sandy land, China. The characteristics of vegetation and soil chemical properties were studied in PSC sites and grazing exclusion sites 0, 6, and 12 years after implementation. Natural community sites were also examined in 2012. Results showed that the implementation of PSC and grazing exclusion not only significantly ($P < 0.05$) promoted the number, density, coverage, and Shannon–Weiner diversity of plant species, but also enhanced the accumulation of total carbon (C) and total nitrogen (N) and accelerated the increase of C/N ratio in soil. In addition, the recovery of vegetation density, coverage, and Shannon–Weiner diversity occurred sooner in the PSC sites than in the grazing exclusion sites. The PSC sites became stable at 6 years. The soil chemical properties also changed more in the PSC sites than in the grazing exclusion sites, but did not become stable state. The restoration of soil chemical properties had a lag effect with respect to vegetation characteristics in degraded sandy grasslands. These findings also suggested that PSC and grazing exclusion are useful methods for accelerating vegetation development and restoring deserted lands. In addition, implementation of PSC was more effective than using grazing exclusion alone. For this reason, it should be adopted in sandy grasslands in the Horqin region in China.

1. Introduction

The Horqin sandy land is one of the most severely degraded areas in northeastern China. The degradation is primarily induced by overgrazing, over-gathering of firewood, and other inappropriate human activities (Cao et al., 2008; Su et al., 2003; Zhang et al., 2004). Desertification results in a number of moving, semi-moving, and stabilized sand dunes. It poses a major threat to the growth of grassland vegetation and farmland crops, and the accumulation of chemicals in soil, resulting in large yield loss (Le Houérou, 2001; Liu and Zhao, 1993; Pei et al., 2008; Whitford, 2002; Wu et al., 2014). To control the spread of desertification and reduce its adverse influence on grassland and farmland, the Chinese government has established large-scale restoration projects. Depending on the degree of ecosystem degradation, one of two restoration methods is typically used: the shrub planting with the protection of straw checkerboard (PSC) and grazing exclusion (Cao et al., 2004; Ge, 2008; Platt, 1977). PSC is a method of restoration that involves artificially assisting the reconstruction of an ecosystem in locations in which it has been overstressed, i.e., to prevent the encroachment of sand dunes into cropland (Cao et al., 2000, 2004; Li, 2005). Grazing exclusion is a simple method of restoration that involves taking advantage of the ability of an understressed ecosystem to restore itself, such as when sand dunes have only moved slightly (Reeves, 2000).

Recently, PSC and grazing exclusion have been confirmed to be successful; they have become common restoration strategies in China (Akiyama and Kawamura, 2007; Cao et al., 2008; Chen et al., 2012; Cheng et al., 2011; Wu et al., 2011). However, the effectiveness of these two methods on the characteristics of vegetation and soil chemical properties has not been well studied.

Abbreviations: PSC, shrub planting with the help of straw checkerboard; PCK, natural *C. microphylla* L. as the PSC control site; GCK, natural grasslands as the grazing exclusion control site.

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In recent years, intensive studies have presented the effects and protective benefits of PSC or grazing exclusion on aboveground vegetation succession and community structure (Courtois et al., 2004; Gibson et al., 2001; Herrera-Arrieta et al., 2011; Loydi et al., 2012; Pettit et al., 1995; Shapotou Desert Research Experiment Station, 1991; Zhang et al., 2004; Zhao et al., 2008). However, very little quantitative research has focused on the effects of PSC and grazing exclusion on soil chemical properties or the effectiveness of restoration methods, especially in areas subjected to different degrees of degradation.

In this study, a 12-year experiment was conducted to monitor characteristics of vegetation and soil properties changes associated with PSC and grazing exclusion in desert lands. The objective of this study was to examine the effects of PSC and grazing exclusion on aboveground vegetation characteristics and soil chemical properties, and determine the effectiveness of these restoration methods in Horqin sandy land. The long-term goal of this research is to contribute to the restoration of degraded sandy grasslands and the protection of the environment in the Horqin region.

2. Methods

2.1. Field site

The experiment was conducted near the Wulanaodu Station of Desertification Research (43°02′N, 119°39′E, 480 m a.s.l.), Chinese Academy of Sciences, in western Horqin sandy land, China. The soil is loose sand, so it is highly susceptible to wind erosion. The average annual temperature is 7.1 °C, ranging from −12.1 °C in January to 23.3 °C in July. Mean precipitation is 292.9 mm, and more than 70% falls during the growing season (from May to September). Annual accumulated temperature above 0 °C was 3781.3 °C from 2000 to 2012 (Fig. 1). The mean annual wind velocity is 4.4 m s^{-1}, and the number of gale days (>20 m s^{-1}) varies between 21 and 80. The dominant direction of the wind is northwestern, with the windy season generally occurring from March to May (Liu et al., 2012). The vegetation in the Horqin area is dominated by *Artemisia halodendron* L., *Artemisia frigida* L. (Compositae), *Caragana microphylla* L. (Leguminosae), *Bassia dasyphylla* L., *Agriophyllum squarrosum* L. (Chenopodiaceae), *Setaria*

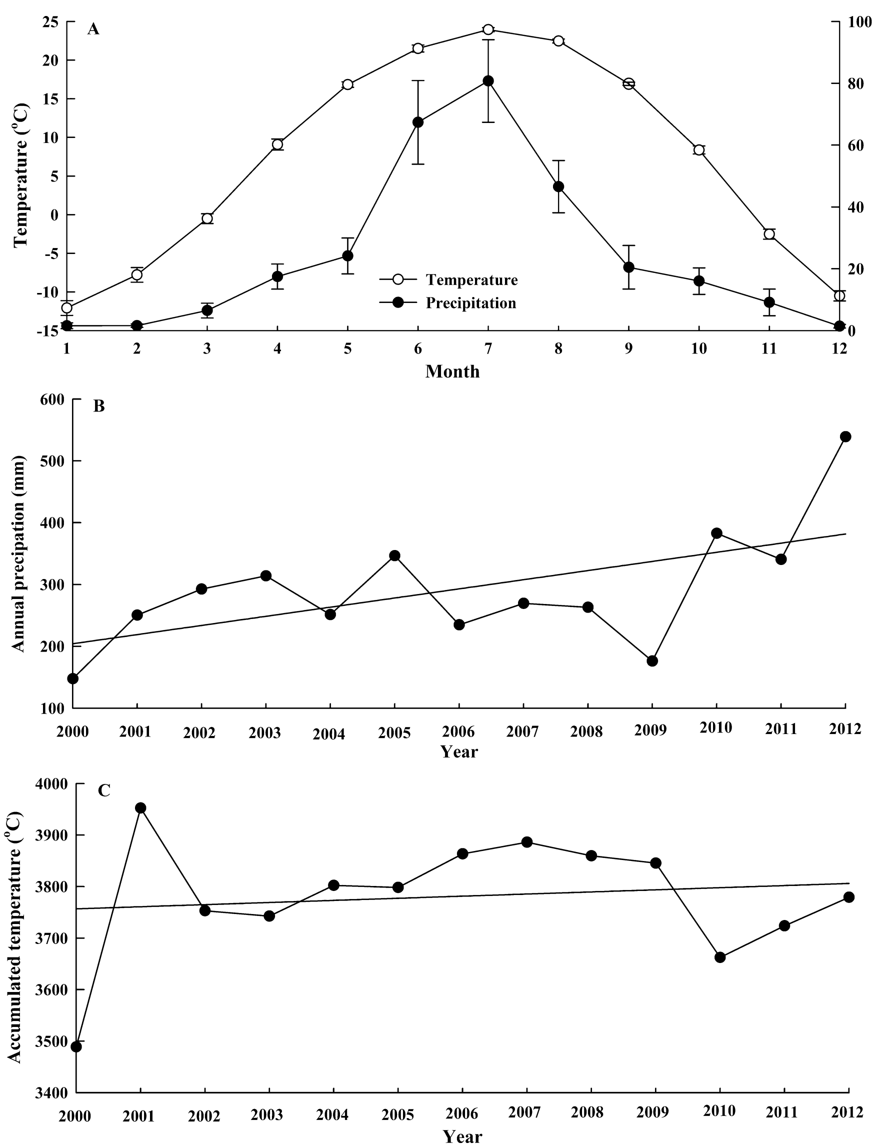

Fig. 1. (A) variation in monthly average temperature and precipitation (±standard error), (B) annual precipitation, and (C) annual accumulated temperature above 0 °C from 2000 to 2012 in the Wulanaodu region.

viridis L., *Chloris virgata* L. (Gramineae), and *Corispermum thelelegium* L. (Asclepiadaceae).

The experimental area has a number of moving and semi-moving sand dunes. These dunes were 300–500 m in length, 30–90 m in width, and 5–10 m in height above interdunal depressions. Before artificial management, the intensity of free grazing in this area was 4.5–5.0 sheep ha^{-1} and had been since the mid-1950s. The restoration area was fenced with 1.2-m-high cement blocks piled together with wire netting (1 m high × 3 m wide) from 2000 and 2006 to 2012. Depending on the degree of degradation of each particular sandy grassland, one of two typical ecological restoration methods was implemented (Platt, 1977). The mobile sand dunes were planted with *C. microphylla* (pioneer species for vegetation reestablishment) with the protection of straw checkerboards; on the semi-mobile sand dunes, only the grazing exclusion method was used. To establish straw checkerboards, lines parallel and perpendicular to the direction of prevailing wind erosion were drawn in the sand dunes, and then straw (0.5 kg per prolonged meter) was well distributed vertically on the lines. The straw stems were inserted into the sand at an approximate depth of 15 cm, and its mean height above the soil surface was approximately 20–25 cm. Then, a shrub (*C. microphylla*) was planted in the center of each square of the straw checkerboard. The grazing exclusion method completely excluded livestock grazing year-round. At that time, there were large PSC and grazing exclusion restoration sites in the surrounding Wulanaodu region. In addition, there were large areas of natural *C. microphylla* and natural grasslands, which served as PSC control sites (PCK) and grazing exclusion control sites (GCK).

2.2. Sampling design and procedure

Research was carried out in late July 2012. This experiment was conducted as follows: (1) PSC and grazing exclusion methods were used as experimental treatments, and each treatment had four levels. (2) The levels included four levels of PSC treatment, including a control level (natural *C. microphylla*) and three PSC levels (PSC lasting 0, 6, and 12 years); and four levels of grazing exclusion treatment, including a control level (natural grassland) and three grazing exclusion levels (grazing exclusion lasting 0, 6, and 12 years). (3) Three representative sand dunes (as three replicates) within each treatment level, each approximately 3–6 ha in area, were selected as the experimental sites, and the sand dunes were at least 400 m apart. (4) A representative plot of each sand dune, approximately 20 m × 30 m in area, was selected for sampling. All the plots were similar in topography and extent. They were in the middle part of the windward slop (at least apart from the edge 10 m distance). (5) Five random quadrats were established in each plot for vegetation and soil research. The quadrat of *C. microphylla* plot was 2 m × 2 m for shrub investigation and 1 m × 1 m for herb research, and the quadrat of grazing exclusion plot was 1 m × 1 m. Soil samples were collected at 1 m × 1 m quadrat in all plots. In each quadrat, vegetation species number and density were recorded by counting, and vegetation coverage was measured using a visual estimation method in late July 2012 (the peak of the growing season). In an investigation of density, a shoot was regarded as an individual plant. Meanwhile, five random soil samples (0–10 cm depth) were collected at least 20 cm from *C. microphylla* in PSC sites. They were randomly collected in grazing exclusion sites using a 5-cm-diameter soil auger in each quadrat. Five soil cores were collected from each quadrat and combined into a single composite sample. Then, all composite samples were air-dried and sieved through a 2-mm screen to remove root particles and litter. Soil pH and electrical conductivity were measured in a soil–water aqueous extract (1:1 and 1:5 soil–water ratio, respectively). Available phosphorus (P) was measured using the Olsen and Dean method (Institute of Soil Sciences, 1978). Part of the samples were sieved to pass a 0.25-mm mesh and analyzed for total carbon (C) and total nitrogen (N). Total C was determined by a SSM-5000A TOC-5000 analyzer (Shimadzu Corporation, 1993). Total N was measured with the Kjeldahl method (Institute of Soil Sciences, 1978).

2.3. Data analysis and statistics

Richness (R), Shannon–Wiener diversity index (H), and Evenness index (E) of the experimental sites were calculated as follows:

Table 1
Species composition for each PSC and grazing exclusion sites.

Species	PSC time (year)				Grazing exclusion (year)			
	0	6	12	PCK	0	6	12	FCK
Adenophora tetraphylla								+
Agriophyllum squarrosum	+				+			
Arenaria serpyllifolia								+
Aristida adscensionis				+	+	+	+	
Artemisia arenaria	+	+	+		+			
Artemisia lavandulaefolia								+
Artemisia tanacetifolia								+
Arundinella hirta								+
Bassia dasyphylla		+	+	+		+	+	
Caragana microphylla		+	+	+				
Carduus nutans							+	
Chenopodium acuminatum			+	+		+	+	
Chenopodium aristatum		+	+					
Chenopodium glaucum				+				
Chloris virgata				+		+		
Cleistogenes squarrosa						+		
Corispermum candelabrum		+	+	+	+	+	+	
Cuscuta chinensis						+	+	
Cynanchum thesioides		+	+	+		+	+	
Diarthron linifolium					+	+		
Digitaria sanguinalis			+	+	+			
Epilobium angustifolium								+
Equisetum arvense								+
Eragrostis poaeoides			+					
Erigeron acer								+
Eupatorium lindleyanum								+
Euphorbia humifusa				+			+	
Geranium sibiricum								+
Glycine soja								+
Hemarthria compressa								+
Hemerocallis citrina								+
Koeleria cristata								+
Kummerowia striata								+
Lactuca indica		+						+
Lathyrus quinquenervius								+
Leonurus japonica		+						
Lespedeza davurica				+				
Leymus chinensis								+
Linum stelleroides								+
Lysimachia barystachys								+
Melissilus ruthenicus			+					+
Miscanthus sacchariflorus								+
Pennisetum centrasiaticum			+					
Peucedanum terebinthaceum							+	
Phragmites australis								+
Polygonum bungeanum								+
Potentilla chinensis								+
Ranunculus chinensis								+
Salsola ruthenica				+			+	
Sanguisorba officinalis								+
Setaria viridis		+	+	+	+	+	+	
Sonchus brachyotus								+
Stellera chamaejasme								+
Taraxacum mongolicum								+
Thalictrum simplex								+
Tribulus terrestris				+				
Number of species present in the sites	2	9	11	15	7	10	10	32

+ Denotes the presence of species.

$$\text{Richness index}(R): R = S,$$

$$\text{Shannon}-\text{Wiener diversity index}(H): H = -\sum_{i=1}^{s}(P_i \ln P_i),$$

$$\text{Evenness index}(E): E = \frac{H}{\ln S},$$

where S is the total number of species present in the plot, and P_i is the density proportion of i species.

One-way ANOVA was used to compare vegetation characteristics (density, coverage, species diversity, and evenness) and soil chemical properties (pH, electrical conductivity, total C, total N, available P, and C/N ratio). Prior to this, homogeneity of variance had been examined using Levene's test. Differences were considered significant at $P < 0.05$ with the LSD *post hoc* test. All results were reported in the form of means ± standard error. All data analyses were performed using the SPSS software package (SPSS for Windows, Version 16.0, Chicago, IL, U.S.).

3. Results

3.1. Changes in vegetation characteristics in PSC and grazing exclusion areas

A total of 56 species belonging to 22 families were recorded in the experimental sites. The dominant families were Gramineae (13 species), Compositae (9 species), Chenopodiaceae (7 species), and Leguminosae (6 species). There were more species in the 6- and 12-year PSC sites (9 and 11 species, respectively) than in the 0-year PSC sites (2 species) but not as many as in the PCK sites (15 species). There were many more species in the 6- and 12-year grazing exclusion sites (both 10 species) than in the 0-year grazing exclusion sites (7 species) but fewer than in the GCK sites (32 species) (Table 1).

3.1.1. Changes in vegetation characteristics in PSC sites

The vegetation density, coverage, and Shannon–Weiner diversity index were significantly higher in the 6- and 12-year PSC and PCK sites than in the 0-year PSC sites ($P < 0.05$), but no significant differences were detected among 6-year and 12-year PSC and PCK sites ($P > 0.05$) (Fig. 2A–C). None of the evenness indexes showed

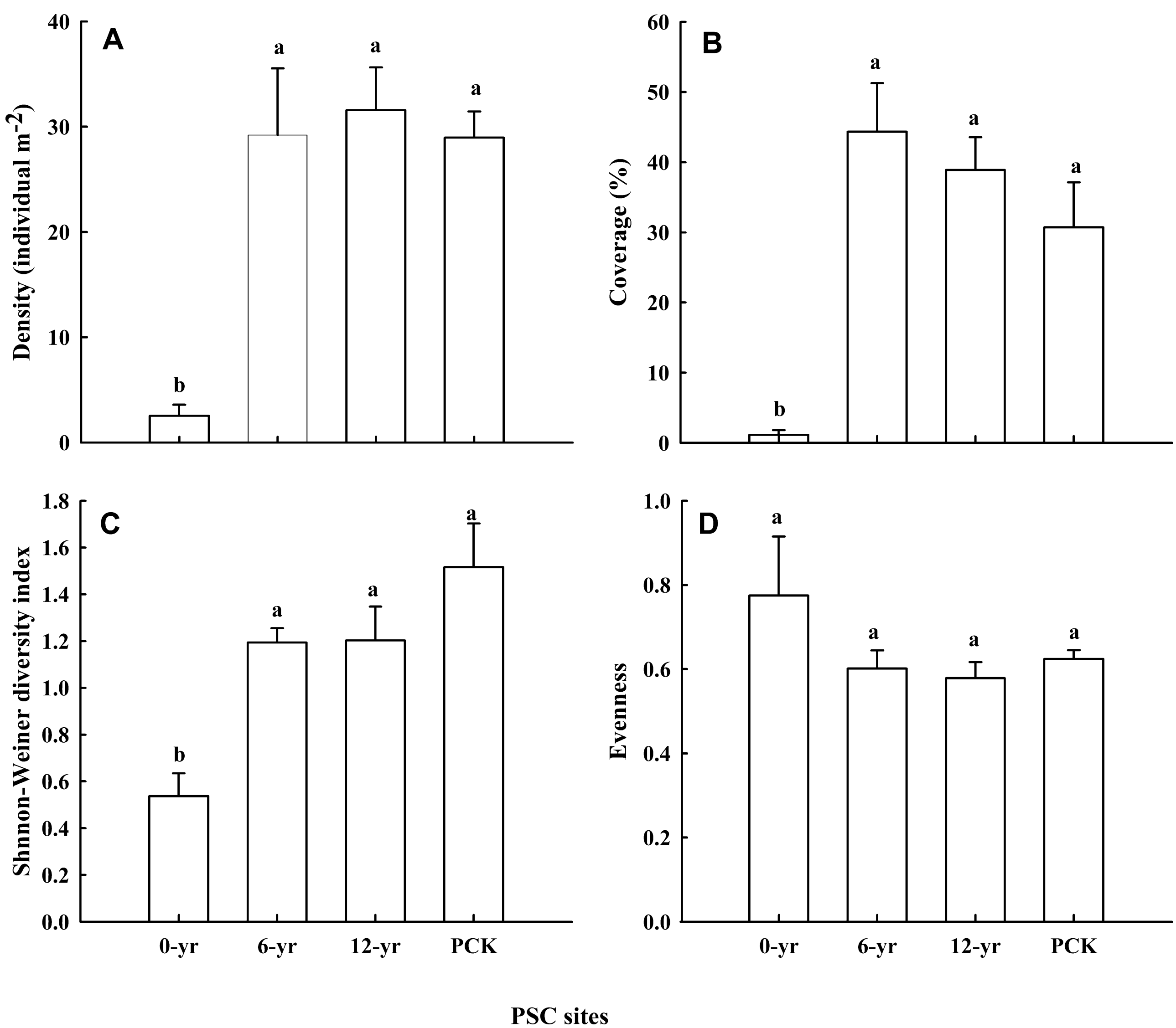

Fig. 2. Variations in (A) vegetation density (individual m^{-2}), (B) coverage (%), (C) Shannon–Wiener diversity index, and (D) evenness index at different PSC sites. Different letters indicate significant differences between PSC sites at $P < 0.05$.

any significant differences at any of the four PSC sites ($P > 0.05$) (Fig. 2D).

3.1.2. Changes in vegetation characteristics in grazing exclusion sites

The vegetation density and coverage was significantly ($P < 0.05$) increased over grazing exclusion time (Fig. 3A and B). The Shannon–Wiener diversity and evenness index was first increased to a high level in the 6-year grazing exclusion sites then decreased (Fig. 3C and D). All vegetation characteristics were significantly ($P < 0.05$) lower in the grazing exclusion sites than in GCK sites, except for vegetation density, which was higher in the GCK sites than in the 0-year grazing exclusion sites, but it was lower than in the 6- and 12-year grazing exclusion sites (Fig. 3A–D).

3.2. Changes in soil chemical properties in PSC and grazing exclusion areas

3.2.1. Changes in soil chemical properties in PSC sites

Electrical conductivity, available P, total C, and total N increased significantly as plantation time increased ($P < 0.05$) (Fig. 4A, and C–E). The pH was significantly higher in the 6-year and 12-year PSC sites than in the 0-year PSC sites ($P < 0.05$), but there were no significant differences between the 6-year and 12-year PSC sites ($P > 0.05$) (Fig. 4B). The C/N ratio was significantly higher in the 12-year PSC sites than in the 0- and 6-year PSC sites ($P < 0.05$). No significant difference was observed between the 0-year and 6-year PSC sites ($P > 0.05$) (Fig. 4F). All soil chemical properties were significantly lower in the PSC sites than in the PCK sites, expect for the available P and C/N ratio ($P < 0.05$). Available P showed no significant difference between the 12-year PSC sites and the PCK sites, and the C/N ratio showed no obvious ($P > 0.05$) difference between the 6-year and 12-year PSC sites and the PCK sites (Fig. 4A–F).

3.2.2. Changes in soil chemical properties in grazing exclusion sites

The electrical conductivity was significantly higher in the 6-year grazing exclusion sites than in the other sites ($P < 0.05$), but there were no significant differences among other sites ($P > 0.05$) (Fig. 5A). The C/N ratio was higher in the 6- and 12-year grazing exclusion and GCK sites than in the 0-year grazing exclusion sites ($P < 0.05$), but there were no significant differences among 6-year and 12-year grazing exclusion and GCK sites ($P > 0.05$) (Fig. 5F). The

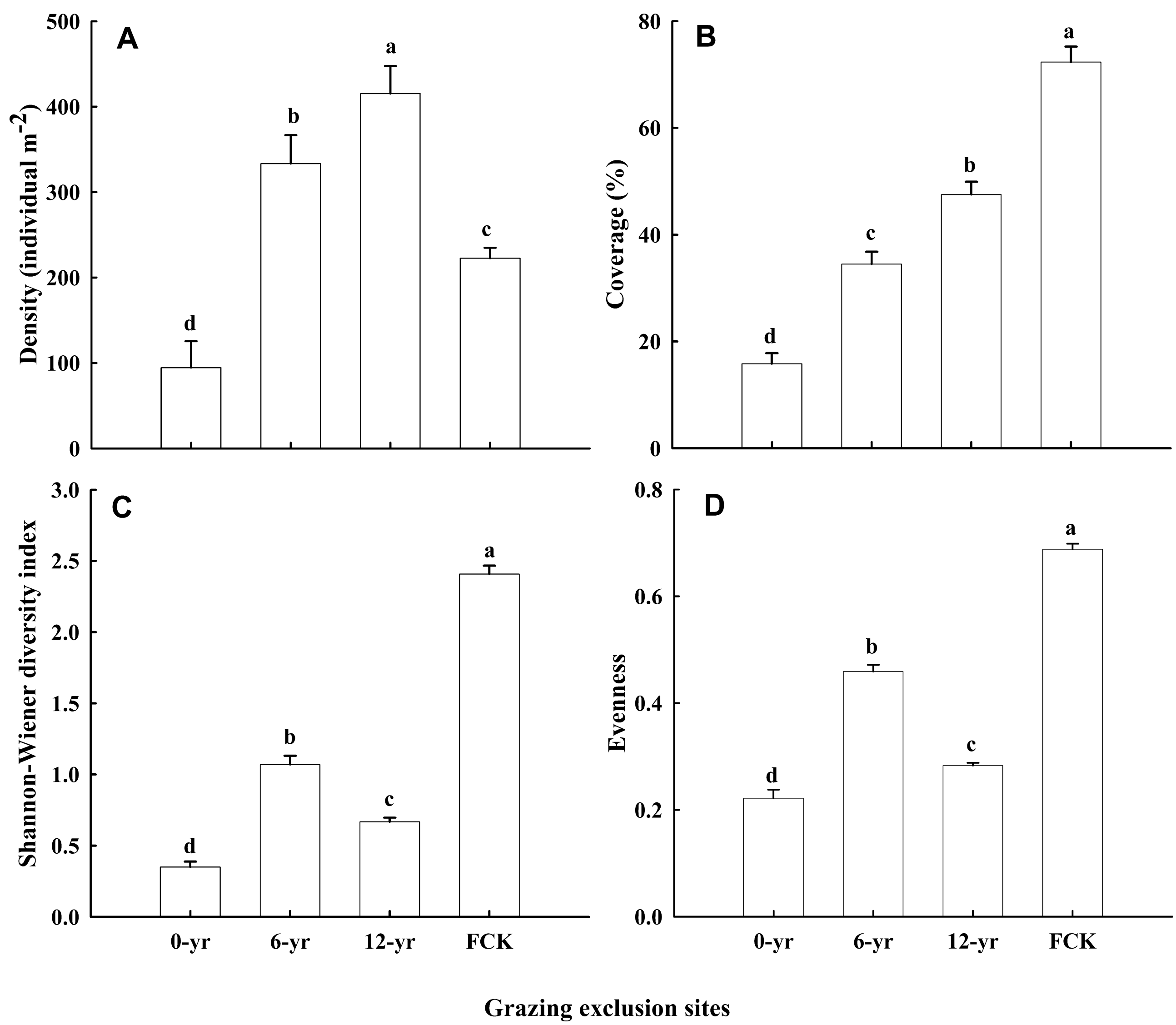

Fig. 3. Variations in (A) vegetation density (individual m^{-2}), (B) coverage (%), (C) Shannon–Wiener diversity index, and (D) evenness index in different grazing exclusion sites. Different letters represent significant differences between grazing exclusion sites at $P < 0.05$.

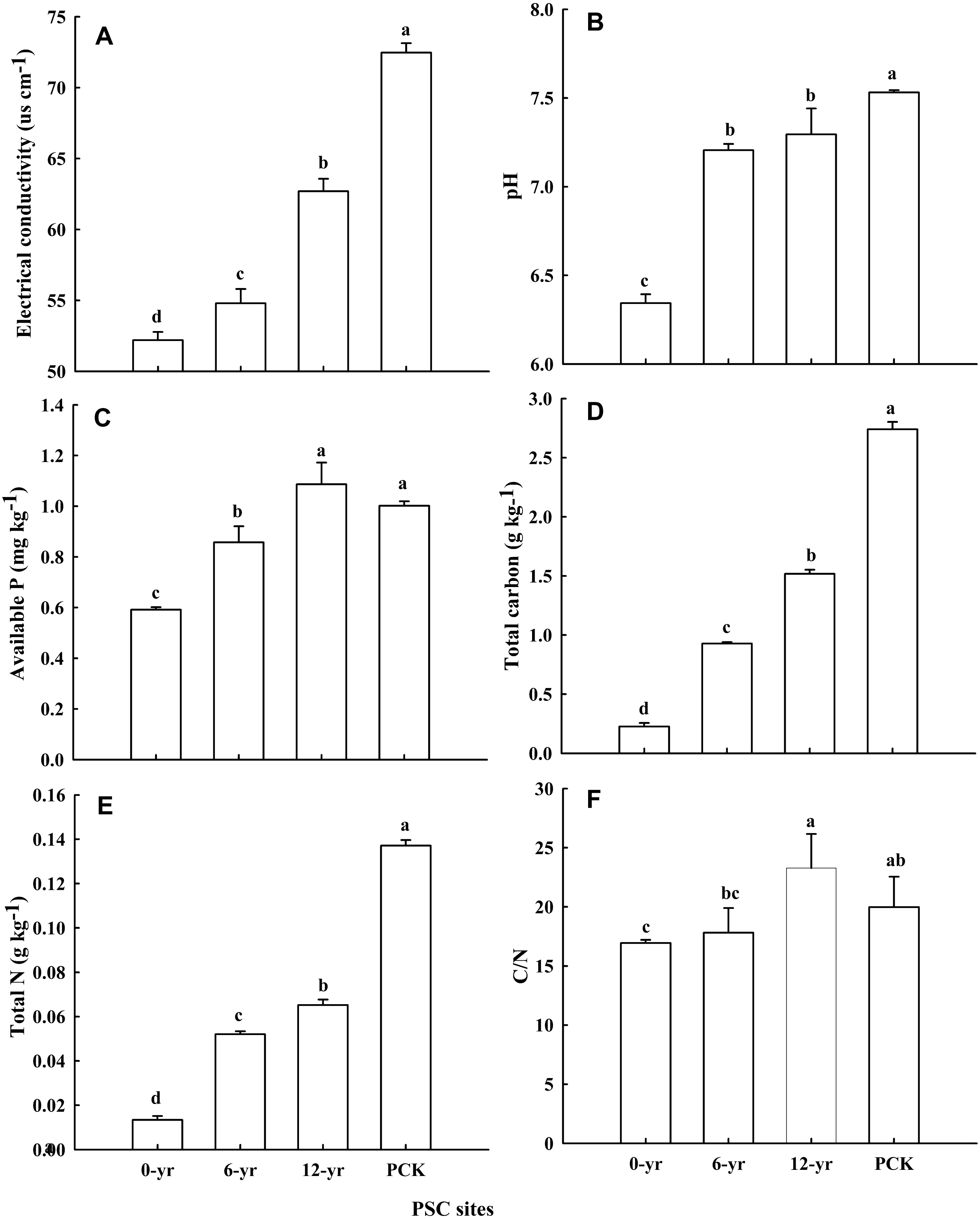

Fig. 4. Variations in (A) electrical conductivity ($\mu s\ m^{-2}$), (B) pH value, (C) available P ($g\ kg^{-1}$), (D) total C ($g\ kg^{-1}$), (E) total N ($g\ kg^{-1}$), and (F) C/N ratio in different PSC sites. Different letters indicate significant differences between PSC sites at $P < 0.05$.

pH was higher in the 6- and 12-year grazing exclusion sites than in the 0-year grazing exclusion sites ($P < 0.05$), and it was lower in the 12-year grazing exclusion sites than in the 6-year grazing exclusion sites ($P < 0.05$) (Fig. 5B). Available P presented no obvious differences among 0-, 6-, and 12-year grazing exclusion sites (Fig. 5C). There were more total C in the 12-year grazing exclusion sites than in the 0-year grazing exclusion sites ($P < 0.05$), but there were no significant differences between 0-year and 12-year grazing exclusion sites and the 6-year grazing exclusion sites ($P > 0.05$) (Fig. 5D). Total N was significantly higher in the 12-year

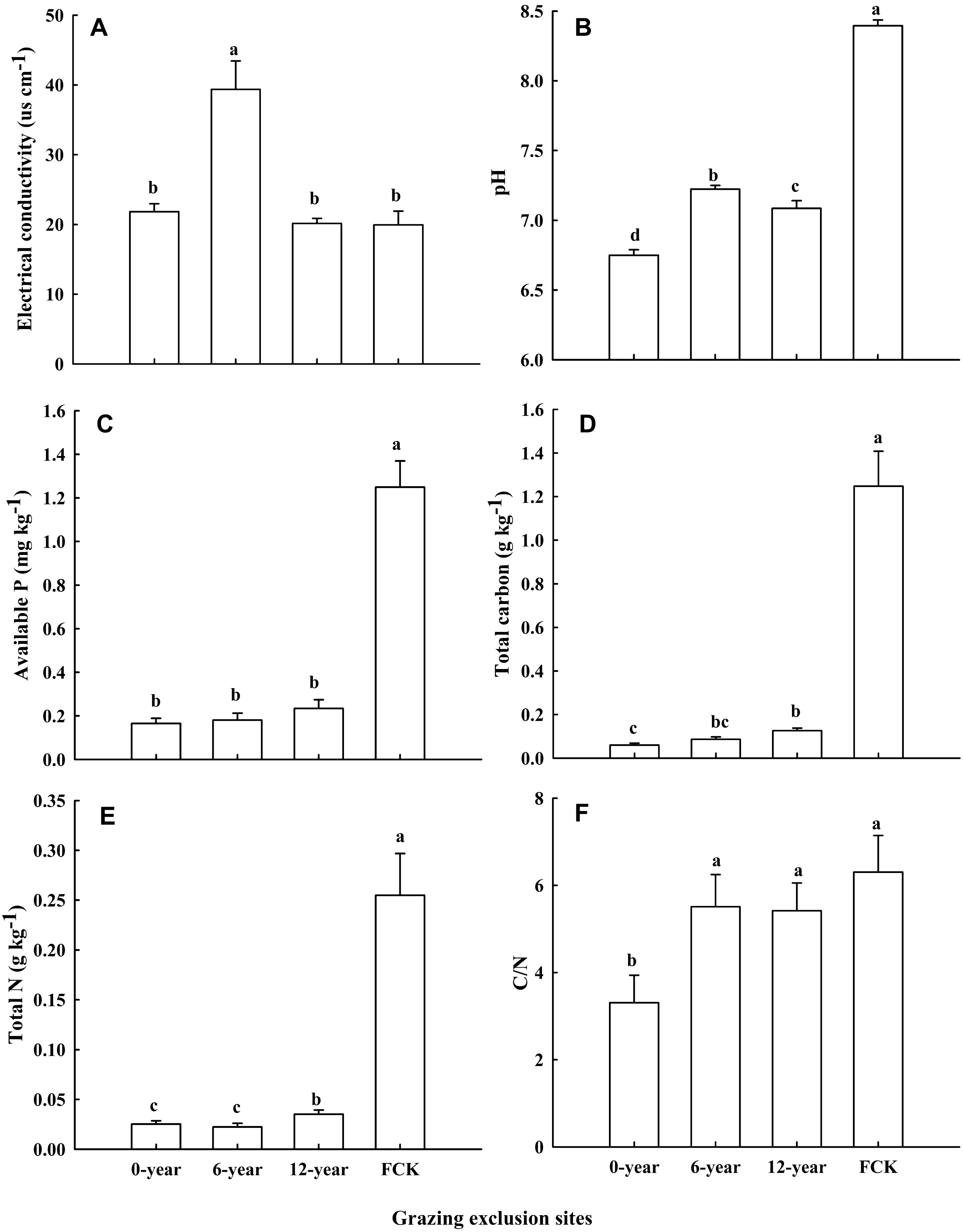

Fig. 5. Variations in (A) electrical conductivity (μs m^{-2}), (B) pH value, (C) available P (g kg^{-1}), (D) total C (g kg^{-1}), (E) total N (g kg^{-1}), and (F) C/N ratio in different grazing exclusion sites. Different letters donate significant differences between grazing exclusion sites at $P < 0.05$.

grazing exclusion sites than in the 0-year and 6-year grazing exclusion sites ($P < 0.05$), but there was no obvious difference between the 0-year and 6-year grazing exclusion sites ($P > 0.05$) (Fig. 5E). The pH, available P, total C, and total N were significantly lower in the grazing exclusion sites than in the GCK sites ($P < 0.05$) (Fig. 5B–E).

4. Discussion

4.1. Effects of PSC and grazing exclusion on degraded sandy grasslands restoration

Many previous studies have stated that the restoration of degraded lands can be evaluated by the vegetation characteristics and soil chemical properties change (Sarmiento et al., 2003; Pei et al., 2008; Zhang et al., 2004). The effects of PSC and grazing exclusion on these characteristics, and therefore, on the methods in desertification control and degraded land restoration, are of great significance (Higgs, 1997; Zhang et al., 2004). The results of this study indicate that vegetation characteristics and soil chemical properties were both altered after the implementation of the restoration methods, but the degree of alternation differed considerably. The numbers of species present, vegetation density, coverage, and Shannon–Weiner diversity index were served as indicators of the degree of restoration of degraded lands (Zhang et al., 2005). These vegetation characteristics were all significantly improved after artificial management ($P < 0.05$) (Table 1,Figs. 2 and 3). This is consistent with studies showing the positive effects of restoration approaches on these vegetation parameters in degraded sandy grasslands (Jeddi and Chaieb, 2010; Li et al., 2009; Pei et al., 2008; Zhang et al., 2004). Presumably, these changes are related to a decrease in soil erosion and an increase in soil nutrient accumulation in a microclimate environment, promoting the regeneration and growth of vegetation (Li et al., 2009; Yates et al., 2000). These changes can protect the surface of the soil, promote soil nutrient accumulation, and increase the speed of colonization by other forms of vegetation (Fullen and Mitchell, 1994; Garner and Steinberger, 1989; Pei et al., 2008; Qiu et al., 2004).

Livestock grazing can result in some energy and nutrient loss from the ecosystem (Zhao et al., 1997; Zhang et al., 2000). Soil nutrient conditions can improve after artificial management is implemented. Soil total carbon is the most important soil property (Schoenholtz et al., 2000). Total N is usually the limiting factor of vegetation restoration in harsh environments (Berg et al., 1997; Day and Ludeke, 1993). The current findings also suggested that total C, total N, and C/N ratio increased considerably over artificial management time (Figs. 4 and 5). This is probably due to the growth and death of vegetation, dust deposition, and the decomposition of straw checkerboards and litter (Cao et al., 2004, 2011; Hu and Zhou, 1991; Whitford, 2002). Other researchers have found that these soil chemical properties become less pronounced as artificial management continues. This is mainly due to increase in chemical uptake by vegetation (Oesterheld et al., 1999; Pei et al., 2008). Therefore, whether or not soil nutrients accumulate depends on the amounts that vegetation uptake decreases and other pathways increase (Ruggiero et al., 2002). These changes demonstrate that the restoration process is progressing. The C/N ratio was found to have increased after artificial management, which demonstrated that the soil carbon accumulation rate is more rapid than the soil N in land-restoration processes. In this way, the restoration sites are a carbon sink to combat climatic warming. The pH is a major factor affecting biodiversity and ecosystem functioning (Chen et al., 2013; Stevens et al., 2010). The pH was higher in artificial management sites than non-management sites. This is consistent with other studies conducted in the Horqin degraded sandy grasslands (Cao et al., 2008; Miao et al., 2013). However, the opposite results were found by Wu et al. (2009) and Jeddi and Chaieb (2010). No significant differences were observed by Li et al. (2006). These differences depended on the amount of organic acid and CO_2 secreted by the roots and microorganisms (Barber and Martin, 1976; Hinsinger et al., 2003). The increase in pH took place mainly by influencing N cycling and soil base mineral cations and increased vegetation coverage and species diversity (Chen et al., 2013). In this way, it promotes ecosystem recovery and sand dune stabilization.

PSC and grazing exclusion were found to be useful methods of recovering vegetation characteristics and soil chemical properties in these degraded lands (moving and semi-moving sand dunes) in the Horqin sandy land. However, the details of restoration time and the effects of restoration methods on the physical and biological properties of soil require further study in degraded sandy grassland management and utilization.

4.2. Difference between PSC and grazing exclusion on the restoration of degraded sandy grasslands

The restoration rates of vegetation characteristics and soil chemical properties differed considerably in PSC and grazing exclusion methods in degraded sandy grasslands. The results showed that vegetation density, coverage, Shannon–Weiner diversity, and evenness index became stable in the 6-year PSC sites, which became very similar to the PCK sites (Fig. 2). These vegetation parameters showed considerable differences among grazing exclusion sites and GCK sites (Fig. 3). Soil chemical properties changed significantly in two methods. They showed profound differences between the PSC method and grazing exclusion method, but most of the properties did not achieve a stable state (Figs. 4 and 5). The current results were consistent with previous findings which were also collected in individuals of northern Chinese desert (Fullen and Mitchell, 1994; Zhang et al., 2004). These differences are mainly attributed to straw checkerboards and *C. microphylla* play an important role in the process of vegetation and land restoration: (1) straw checkerboard can increase the surface roughness and soil water-holding capacity of sand dunes and stabilize them to decrease wind erosion and encourage vegetation colonization (Danin et al., 1989). (2) Decomposition of straw checkerboards can increase surface soil nutrient contents markedly (Drees et al., 1993; Hu and Zhou, 1991). (3) *C. microphylla* can promote storage and conservation for species, provide habitat, and seed sources for vegetation, and foster a fertility island effect (Garner and Steinberger, 1989; Li et al., 2010). In this way, PSC is more effective in the restoration of vegetation characteristics and soil chemical properties in degraded sandy grasslands than pure grazing exclusion. In addition, soil chemical properties recover more slowly than vegetation characteristics in these artificial management areas. However, the details of the restoration pace of vegetation characteristics and soil chemical properties in quantifying nutrient content are unclear and require further study. In terms of economic costs, PSC needs 0.95 yuan RMB per prolonged meter, and grazing exclusion requires a much smaller investment.

Judging from the degree of ecosystem degradation and the urgent need for stability in the region, the PSC method should be used in moving and semi-moving sand dunes where the need for stability is urgent (e.g., railways, roads, villages), and grazing exclusion can be considered for non-urgent stabilization of semi-moving sand dunes.

5. Conclusions

PSC and grazing exclusion are two key techniques suitable for stabilizing degraded sandy grasslands (moving and semi-moving sand dunes) and restoring vegetation characteristics and soil chemical properties, which have been widely used in many arid and semi-arid regions of China. To conclude, these two methods can significantly: (1) increase vegetation species number, density, coverage, and Shannon–Weiner diversity, and (2) enhance the addition of total C, total N, and C/N ratio in soil. The restoration of soil chemical properties showed a lag effect with respect to changes in vegetation characteristics under both artificial management systems. However, the pace of restoration of vegetation characteristics and soil chemical properties was faster in PSC sites than in the grazing exclusion sites. All of these findings showed that both PSC and grazing exclusion were useful methods of accelerating vegetation recovery and protecting the environment. Moreover, PSC was more effective than pure grazing exclusion in stabilizing degraded sandy grasslands. It is here suggested that PSC should be considered first as a beneficial method of management of degraded sandy grasslands from an ecological viewpoint, and that grazing exclusion can also be considered for semi-moving sand dunes where stabilization is not urgent.

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