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Soil Seed Bank and Plant Community Development in Passive Restoration of Degraded Sandy Grasslands

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Abstract: To evaluate the efficacy of passive restoration on soil seed bank and vegetation recovery, we measured the species composition and density of the soil seed bank, as well as the species composition, density, coverage, and height of the extant vegetation in sites passively restored for 0, 4, 7, and 12 years (S0, S4, S7, and S12) in a degraded grassland in desert land. Compared with S0, three more species in the soil seed bank at depths of 0–30 cm and one more plant species in the community was detected in S12. Seed density within the topsoil (0–5 cm) was five times higher in S12 than that in S0. Plant densities in S7 and S12 were triple and quadruple than that in S0. Plant coverage was increased by 1.5 times (S4), double (S7), and triple (S12) compared with S0. Sørensen's index of similarity in species composition between the soil seed bank and the plant community were high (0.43–0.63), but it was lower in short-term restoration sites (S4 and S7) than that in no and long-term restoration sites (S0 and S12). The soil seed bank recovered more slowly than the plant community under passive restoration. Passive restoration is a useful method to recover the soil seed bank and vegetation in degraded grasslands.

Keywords: desertification; grazing exclusion; passive restoration; Sørensen's index of similarity (IS)

1. Introduction

Desertification of sandy areas in Northeast China, which is primarily triggered by overgrazing [1,2], poses a serious threat to ecosystem structure and function, resulting in reduced productivity [3]. Restoration methods such as passive restoration (*i.e.*, removing domestic grazers) and active restoration (*i.e.*, replanting target plant) have been widely used in degraded sandy grasslands [4–7]. Recently, some ecologists have documented that passive restoration of degraded lands should be considered first because passive restoration relies on the natural succession of a regressive ecosystem to drive recovery without anthropogenic help, which has also excluded the disturbance of domestic animals (*i.e.*, cattle, sheep) [8–10]; thus, the cost is much cheaper than the active method. In addition, passive restoration methods are as effective as active restoration [11,12]. Thus, passive restoration has mostly been employed in degraded sandy grasslands of semi-arid regions [1,2,13].

Previous studies of passive restoration in degraded ecosystems have found that passive restoration had positive [14–17], neutral [18], or even negative effects [19] on the species composition and density of the soil seed bank, as well as on the species composition, density, coverage, and mean height of vegetation. The different results mainly depended on the variety in seed production and emergence capacity, plant growth and dispersal, and the ratio of weeds to grass across the different grasslands [15].

The similarity between the species composition of the soil seed bank and vegetation may increase [20], decrease [21], or not change [15,22] after disturbance has been excluded from degraded grasslands. The contradictory results were attributed to variations in (1) the plant dispersal capacity; (2) the proportion of the extant plants derived from the soil seed bank (*vs.* dispersal into the site from outside); (3) the production and species richness of mature vegetation; and (4) the relative proportions of persistent soil seed bank. Previous studies have reported that high similarity occurred in communities with weak plant dispersal capacity and high vegetation productivity and species richness, whereas low similarity occurred under the opposite conditions [23–25]. However, understanding of the development of these ecosystem characteristics over time is still limited for degraded, semi-arid sandy grasslands managed using passive restoration.

A chronosequence of sites in Inner Mongolia under passive restoration method (0, 4, 7, and 12 years) were employed to quantify the recovery and similarity of the soil seed bank and vegetation. The objective of this study was to quantify the effects of passive restoration on (1) the species composition and density of the soil seed bank; (2) the species composition, density, coverage, and mean height of extant vegetation; and (3) the Sørensen's index of similarity (IS) between the soil seed bank and vegetation community. The results can provide a basis for understanding about the passive restoration effects on the soil seed bank and vegetation recovery, and will inform and promote policy made for protection and restoration in degraded grasslands.

2. Materials and Methods

2.1. Field Site

The study was conducted at the Wulanaodu Experimental Station of Desertification (43°02′N, 119°39′E, 480 m a. s. l.) in the western part of Horqin Sandy Land in Northeastern Inner Mongolia, China. The climate is semi-arid continental, with a mean annual precipitation of 340.5 mm and more than 70% of this precipitation occurred during the growing season (from May to September). Mean annual pan evaporation is 2000–2500 mm, six to seven times greater than the annual rainfall amount. Average annual temperature is 6.3 °C, and the coldest and warmest months are January and July, with mean temperatures of −14.0 °C and 23.0 °C, respectively. Mean annual wind velocity is 4.4 $m \cdot s^{-1}$, and wind direction is predominantly northwestern. Gale days (>20 $m \cdot s^{-1}$) occur 21–80 times per year, with the windy season generally occurring from early April to late May. The native dominant plant community types were the *Caragana microphylla* community, the *Cleistogenes squarrosa* community, the *Leymus chinensis*–rank grass community, the *Arundinella hirta*–*Hemarthia altissima* community, the *Spodiopogon sibiricus*–rank grass community, the *A. hirta*–rank grass community, the *Phragmites communis*–rank grass community, the *L. chinensis* community, and the *H. altissima*–*P. communis* community [26]. The original communities have changed greatly following centuries of exploitation and over-grazing. The extant vegetation in degraded grassland is dominated by the target plant (*C. microphylla*), pioneer plants (*Artemisia halodendron*, *A. frigida, Bassia dasyphylla*, *Corispermum thelelegium*, and *Agriophyllum squarrosum*), and ruderal species (*Setaria viridis* and *Chloris virgate*).

In the Horqin Sandy Land, grazing was the main disturbance that led to long-term serious land degradation. Free grazing intensity was 4.5–5.0 sheep ha^{-1} since the mid-1950s, which seriously exceeded a moderate grazing rate of 1.0–1.5 sheep ha^{-1} in this area, and induced the amounts of sand dunes. Passive restoration areas of at least 50 m × 50 m were established in 2000, 2005, and from 2008 to 2012. The areas were fenced with 1.2-m-high cement blocks piled together with wire netting (1 m high × 3 m wide) to completely exclude livestock grazing since restoration established. This produced a chronosequence of sites that were 4, 7, and 12 years old by 2012 (referred to as S4, S7, and S12, respectively). Meanwhile, freely grazing sites were treated as the control treatment (S0). The distance between two adjacent restored sites is at least 400 m.

2.2. Sampling Design and Procedure

In April 2012, a control (S0) and three restoration (S4, S7, and S12) levels were selected as the experimental treatments, and the objective reference community (merely mowing in the winter) were dominated as the *C. microphylla* community, the *L. chinensis* community, the *Cleistogenes squarrosa* community, and the *A. hirta* community. Three sand dunes within each treatment area (as three replicates) were randomly selected as the research sites. The sand dunes had a similar soil texture and topography. A plot (10 m × 30 m) was set up in the middle of the windward slope of each sand dune. Ten sampling quadrats (1 m × 1 m) were randomly established in each plot, for a total of 120 quadrats (four treatments × three replicates × ten quadrats). In late April 2012, after the windy season but prior to the rainy season, soil samples were collected from each quadrat at four depths (0–5, 5–10, 10–20, and 20–30 cm) with a 7-cm diameter soil auger following with a previous study in this area [27]. A total of 480 soil samples (120 quadrats × 4 depths) were collected and air-dried. The soils were passed through a 0.5-mm sieve, and the seeds were picked out and identified to the species level by comparing with seeds collected from living plants in 2011. Any seeds that could not be identified were identified using a germination experiment in trays (16 cm in diameter × 1 cm deep) in a greenhouse. All seeds were made viable using the "terazolium dyeing method" before germination [28]. A plant survey was conducted in late July 2012 at the peak of the growing season. A quadrat of 1 m × 1 m quadrat was established at a distance of 50 cm from each soil seed sampling quadrats, and plant species were counted in each quadrat. We considered a plant shoot to be an individual plant for our species density calculations. Plant coverage was measured using a metal frame of 1 m × 1 m with 100 equally distributed grids above the quadrat. The mean plant height was calculated from ten random height measurements, with height measured from the base of the plant (ground level) to the tip of the plant.

2.3. Data Analysis

The similarity of the species composition between the soil seed bank and vegetation community was calculated using the binary Sørensen index of similarity (*IS*) [29] with the flowing equation. Because the soil seed bank can only sample as volume, and the vegetation is calculated as area, which is a different sample method, it is difficult to compare the data, as they do not have the same technical sampling.

$$IS = \left(\frac{2C}{A+B}\right) \times 100\%$$

where C is the number of species that the soil seed bank and plant community had in common, and A and B are the total number of species in the soil seed bank and plant community, respectively.

One-way ANOVA was used to compare the density of the soil seed bank, the density, coverage, and mean height of the plant, as well as the *IS* among the four treatments. Differences between each pair of treatments were tested with a *post hoc* Tukey HSD at a $p < 0.05$ level. Normal distribution and homogeneity of variances were examined by the Shapiro–Wilk test and Levene's test before the above analysis was conducted. Statistical analyses were performed with the SPSS 16.0 software package (SPSS Inc., Chicago, IL, USA).

3. Results

3.1. Soil Seed Bank Recovery

The soil seed bank contained eight species from five families. All species were annual plants except for *C. microphylla* (a shrub) found in S12, which is the typical species of the target community. Species number was increased from three in S0 to five, four, and six in S4, S7, and S12, respectively (Table 1). The seed density from 0 to 30 cm was five times higher in S12 than that in S0, primarily because of the elevated seed number in the topsoil (0–5 cm), which explained 96% of the variation on soil seed density (Figure 1).

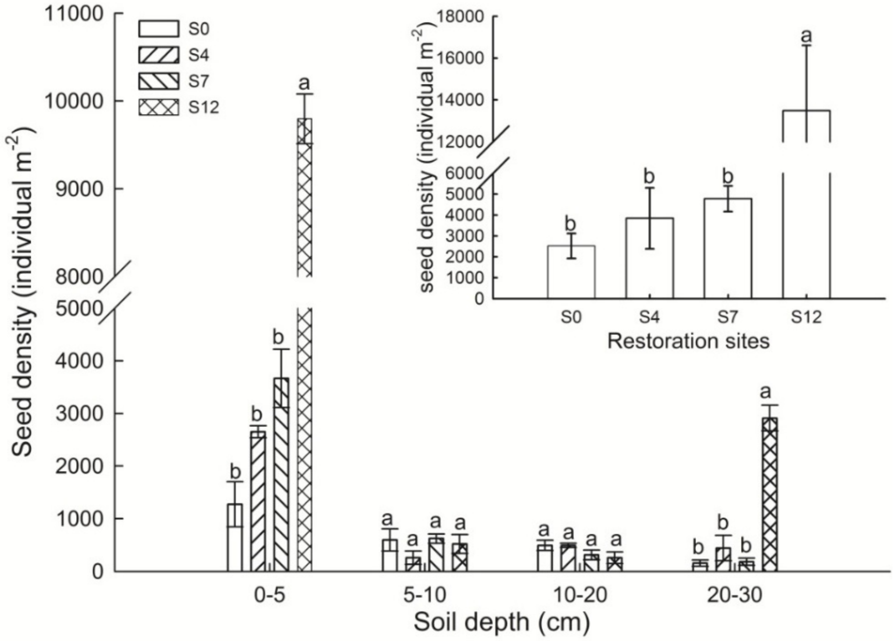

Figure 1. Soil seed density (individual m^{-2}) at different soil depths (cm) and sites (S0, S4, S7, and S12). Insert chart shows total soil seed density for 0–30 cm. Different letters indicate a significant difference ($p < 0.05$).

Table 1. List of species recorded in the soil seed bank and vegetation community under the four treatments. +: present in the research sites; −: absent in the research sites.

Species	Family	Soil Seed Bank				Vegetation			
		S0	S4	S7	S12	S0	S4	S7	S12
Aristida adscensionis	Poaceae	−	+	+	+	+	+	+	+
Artemisia arenaria	Compositae	−	−	−	−	+	+	−	−
Atraphaxis bracteata	Polygonaceae	−	+	−	−	−	−	−	−
Agriophyllum squarrosum	Amaranthaceae	+	+	+	+	+	+	−	−
Bassia dasyphylla	Amaranthaceae	−	−	−	+	+	−	+	+
Chenopodium acuminatum	Amaranthaceae	−	−	−	−	−	−	+	+
Corispermum candelabrum	Amaranthaceae	+	−	+	+	+	+	+	+
Cuscuta chinensis	Convolvulaceae	−	−	−	−	−	+	+	+
Caragana microphylla	Leguminosae	−	−	−	+	+	+	−	+
Carduus nutans	Compositae	−	−	−	−	+	+	−	+
Cleistogenes squarrosa	Poaceae	−	−	−	−	−	−	+	−
Cynanchum thesioides	Apocynaceae	−	−	−	−	+	+	+	+
Chloris virgata	Poaceae	−	−	−	−	−	−	+	−
Diarthron linifolium	Thymelaeaceae	−	+	−	−	+	+	+	−
Digitaria sanguinalis	Poaceae	−	−	−	−	+	+	+	+
Echinops gmelinii	Compositae	−	−	−	−	−	+	−	−
Euphorbia humifusa	Euphorbiaceae	−	−	−	−	+	+	+	+
Eragrostis minor	Poaceae	−	−	−	−	−	−	+	+
Hedysarum fruticosum	Leguminosae	−	−	−	−	−	+	−	−
Lespedeza davurica	Leguminosae	−	−	−	−	+	+	−	+
Lactuca indica	Compositae	−	−	−	−	−	−	−	+
Rochelia leiosperma	Boraginaceae	−	−	−	−	−	−	+	−
Salsola ruthenica	Amaranthaceae	−	−	−	−	−	−	+	+
Setaria viridis	Poaceae	+	+	+	+	+	+	+	+
Tribulus terrestris	Zygophyllaceae	−	−	−	−	+	+	−	−

3.2. Plant Recovery

We counted 24 species of plants from nine families, with 14 species in S0, 16 in S4, 15 in S7, and 15 in S12 (Table 1). The dominant families were Poaceae (six species), Amaranthaceae (five species), and Asteraceae (four species). Only *C. microphylla* and *Cleistogenes squarrosa* were typical species of the target community. The rest were pioneer species (e.g., *B. dasyphylla*, *Corispermum thelelegium*) and ruderals (*S. viridis* and *C. virgate*) (Table 1). Annuals species (*i.e.*, *Corispermum candelabrum*, *S. viridis*) accounted for 57% plant density in S0, 50% in S4, 80% in S7, and 67% in S12. Compared with S0, plant density was doubled in S7 and tripled in S12. Plant coverage was increased by 1.18 and 1.99 times in S7 and S12, respectively, and plant height was increased by 0.72 and 1.22 times in S4 and S7 compared with S0 (Figure 2).

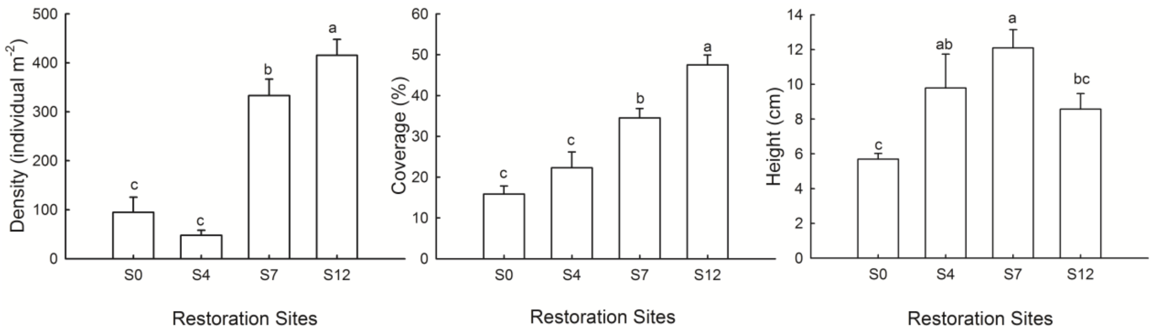

Figure 2. Density (individual m^{-2}), coverage (%), and mean height (cm) of vegetation at the sites (S0, S4, S7, and S12). Different letters indicate a significant difference ($p < 0.05$).

3.3. Restoration Effects on IS Values

The *IS* values were generally high (from 0.43 to 0.63); however, *IS* decreased in non-chronological order with S0 > S12 ⩾ S4 ⩾ S7 (where > indicates a significant difference, and ⩾ indicates a slight but not significant difference at $p = 0.05$) (Figure 3).

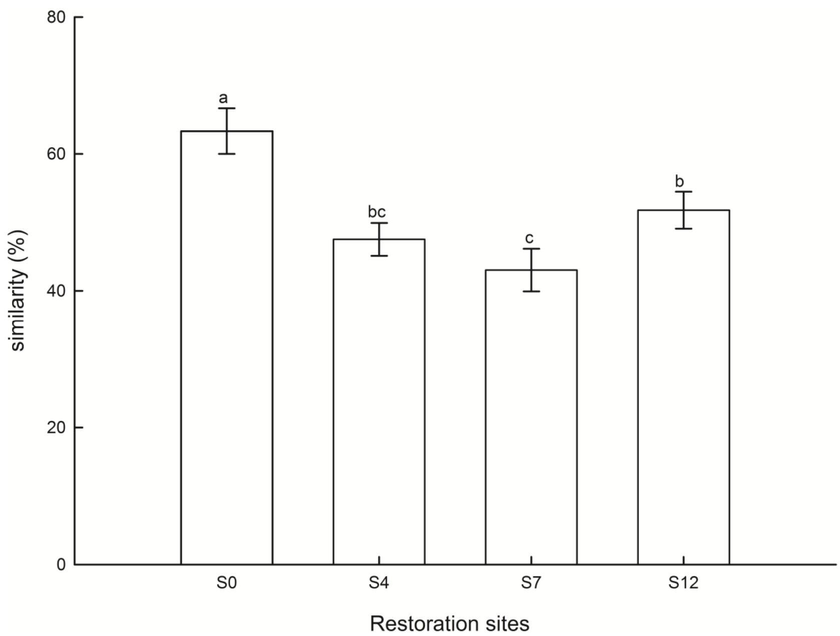

Figure 3. Sørensen similarity index between the soil seed bank and vegetation species composition at the sites (S0, S4, S7 and S12). Different letters indicate a significant difference ($p < 0.05$).

4. Discussion

4.1. Soil Seed Bank Recovery

Successful ecosystem restoration primarily depends on the suitability and adaptability of the vegetation [30]. Plants regrow from seeds in the soil seed bank and extant plant reproduction, or are introduced by dispersal [31,32]; thus, the characteristics of the soil seed bank are important in determining the regeneration potential and resilience of the target community [17,33,34]. Our findings suggest that passive restoration can increase the number of species and their seed density in the soil seed bank, increasing ecosystem resilience [34–36]. However, Sun *et al.* (2005) and Li *et al.* (2012) observed an opposite effect of passive restoration on seed density [17,37]. These conflicting results may be attributed to the differences in seed sources and persistent seed bank reserves at different research sites [29,38]. Our findings show that the soil seed bank had partially recovered, but that restoration is a relatively slow, long-term process.

4.2. Plant Recovery

Plant community composition, density, and coverage are indicators for the restored lands extant vegetation evaluation [7,39]. We found that passive restoration significantly increased plant density, coverage, and slightly increase the plant height; these increased plant community characters can also change the species composition of the soil seed bank by increasing seed production [40]. The results are consistent with Fernández-Lugo (2009), Jeddi & Chaieb (2010), and Li *et al.* (2012), who also investigated sandy grasslands [16,17,41]. Fernández-Lugo (2009) and Gomaa (2012) argued that grazing cessation and microhabitat improvements (mainly increased soil nutrient and water availability) altered the proportions of the dominant species and thus increased plant density, coverage, and height [41,42]. At our sites, the target species (*C. microphylla* and *C. Squarrosa*) are still present, essentially priming the sites for restoration. However, the recovery of the soil seed bank is slower than that of the plant community in our study, because plants regrew from both the soil seed bank and seeds dispersed from the surroundings, as observed in other restored sandy grasslands [26].

4.3. Similarity in Species Composition between the Soil Seed Bank and Vegetation

The *IS* values in all of our sites are higher than those in previous grassland studies [28,29], possibly because of differences in the ratio of perennials to annual species (*IS* typically decreases with an increasing ratio of perennial to annual species) [1,42]. Lower *IS* values in S4 and S7 comparing with S0, partially because the dormancy seed would not regenerate easily without dormancy breaking, indicating that during initial recovery, new species which are not present in the soil seed bank can be added through dispersal from the surrounding area. These results suggest that the species composition of the soil seed bank can be predicted with extant vegetation to some degree, and the recovery of soil seed bank and vegetation needs a relatively long period.

5. Conclusions

Our findings suggest that (1) long-term (12 years) passive restoration management can increase the species number and density of soil seeds, but short-term management (4 and 7 years) had minimal effects on these characteristics; (2) passive restoration can increase the species number, density, and coverage of the target vegetation community; and (3) the recovery of the soil seed bank was slower than that of the plant community. Our study has proved that passive restoration is a beneficial method for sandy grasslands management. Nonetheless, restoration interventions such as direct seeding and planting improve both the regeneration of plant species and land cover.

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Conflicts of Interest: The authors declare no conflict of interest.

References

1. Zhao, L.P.; Su, J.S.; Wu, G.L.; Gilet, F. Long-term effects of grazing exclusion on aboveground and belowground plant species diversity in a steppe of the Loess Plateau, China. *Plant Ecol. Evol.* **2011**, *144*, 313–320. [CrossRef]
2. Li, X.L.; Gao, J.; Brierley, G.; Qiao, Y.M.; Zhang, J.; Yang, Y.W. Rangeland degradation on the Qinghai-Tibet Plateau: Implications for rehabilitation. *Land Degrad. Dev.* **2013**, *24*, 72–80. [CrossRef]
3. Ding, Y.J.; Mu, M.; Zhang, J.Y.; Jiang, T.; Zhang, T.J.; Wang, C.Y.; Wu, L.X.; Ye, B.S.; Bao, M.Z.; Zhang, S.Q. *Impacts of Climate Change on the Environment, Economy, and Society of China. Climate and Environmental Change in China: 1951–2012*; Springer: Berlin, Germany, 2015.
4. Cao, C.Y.; Jiang, D.M.; Teng, X.H.; Jiang, Y.; Liang, W.J.; Cui, Z.B. Soil chemical and microbiological properties along a chronosequence of *Caragana microphylla* Lam. plantations in the Horqin sandy land of Northeast China. *Appl. Soil Ecol.* **2008**, *40*, 78–85. [CrossRef]
5. Wu, G.L.; Li, W.; Zhao, L.P.; Shi, Z.H. Artificial management improves soil moisture, C, N and P in an alpine sandy meadow of western China. *Pedosphere* **2011**, *21*, 407–412. [CrossRef]
6. Jeddi, K.; Chaieb, M. Restoring degraded arid Mediterranean areas with exotic tree species: Influence of an age sequence of *Acacia salicina* on soil and vegetation dynamics. *Flora* **2012**, *207*, 693–700. [CrossRef]
7. Miao, R.H.; Jiang, D.M.; Musa, A.; Zhou, Q.L.; Guo, M.X.; Wang, Y.C. Effectiveness of shrub planting and grazing exclusion on degraded sandy grassland restoration in Horqin sandy land in Inner Mongolia. *Ecol. Eng.* **2015**, *74*, 164–173. [CrossRef]
8. Ren, H.; Du, W.B.; Wang, J.; Yu, Z.Y.; Guo, Q.F. The natural restoration of degraded rangeland ecosystem in Heshan hill land. *Acta Ecol. Sin.* **2007**, *27*, 3593–3600.
9. Wu, G.L.; Liu, Z.H.; Zhang, L.; Chen, J.M.; Hu, T.M. Long-term fencing improved soil properties and soil organic carbon storage in an alpine swamp meadow of western China. *Plant Soil* **2010**, *332*, 331–337. [CrossRef]
10. Zahawi, W.A.; Reid, J.L.; Holl, K.D. Hidden costs of passive restoration. *Restor. Ecol.* **2014**, *22*, 284–287. [CrossRef]
11. Bradshaw, A. The use of natural processes in reclamation—Advantages and difficulties. *Landsc. Urban Plan* **2000**, *51*, 89–100. [CrossRef]
12. Prach, K.; Hobbs, R.J. Spontaneous succession *versus* technical reclamation in the restoration of disturbed sites. *Restor. Ecol.* **2008**, *16*, 363–366. [CrossRef]
13. Wang, Z.J.; Wang, S.X.; Pan, Z.B.; Guo, Y.Z.; Chen, Y.Y. Influence of different recover measures on species structure and variety in Mu Us sandy land. *Chin. J. Ecol.* **2005**, *24*, 464–466.
14. Liu, M.Z.; Jiang, G.M.; Yu, S.L.; Li, Y.G.; Li, G. The role of soil seed banks in natural restoration of the degraded Hunshandak Sandlands, Northern China. *Restor. Ecol.* **2009**, *17*, 127–136. [CrossRef]
15. Shang, Z.H.; Yang, S.H.; Wang, Y.L.; Shi, J.J.; Ding, L.M.; Long, R.J. Soil seed bank and its relation with above-ground vegetation along the degraded gradients of alpine meadow. *Ecol. Eng.* **2016**, *90*, 268–277. [CrossRef]
16. Jeddi, K.; Chaieb, M. Changes in soil properties and vegetation following livestock grazing exclusion in degraded arid environments of South Tunisia. *Flora* **2010**, *205*, 184–189. [CrossRef]
17. Li, Y.Y.; Dong, S.K.; Wen, L.; Wang, X.X.; Wu, Y. Soil seed banks in degraded and revegetated grasslands in the alpine region of the Qinghai-Tibetan Plateau. *Ecol. Eng.* **2012**, *49*, 77–83. [CrossRef]
18. Meissner, R.A.; Facelli, J.M. Effects of sheep exclusion on the soil seed bank and annual vegetation in chenopod shrublands of South Australia. *J. Arid Environ.* **1999**, *42*, 117–128. [CrossRef]
19. Russi, L.; Cocks, P.S.; Roberts, E.H. Seed bank dynamics in a Mediterranean grassland. *J. Appl. Ecol.* **1992**, *29*, 763–771. [CrossRef]
20. Ma, M.J.; Zhou, X.H.; Du, G.Z. Role of soil seed bank along a disturbance gradient in alpine meadow on the Tibet plateau. *Flora* **2010**, *205*, 128–134. [CrossRef]

21. Ungar, I.A.; Woodell, S.R.J. Similarity of seed banks to aboveground vegetation in grazed and ungrazed salt marsh communities on the Gower Peninsula, South Wales. *Int. J. Plant Sci.* **1996**, *157*, 746–749. [CrossRef]
22. Zhao, L.P.; Cheng, J.M.; Su, J.S. The role of soil seed bank in vegetation succession under grazing exclusion in Stipa bungeana grasslands on the Loess Plateau. *Acta Pratacult. Sin.* **2012**, *21*, 38–44.
23. Bossuyt, B.; Hermy, M. Seed bank assembly follows vegetation succession in dune slacks. *J. Veg. Sci.* **2004**, *15*, 449–456. [CrossRef]
24. Li, Y.L. Floristic composition of vegetation and the soil seed bank in different types of dunes of Kerqin steppe. *Arid Land Res. Manag.* **2004**, *18*, 283–293. [CrossRef]
25. Kristine, N.H. A review of similarity between seed bank and standing vegetation across ecosystems. *Oikos* **2007**, *116*, 1438–1448.
26. Cao, C.Y.; Jiang, D.M.; Zhu, L.H.; Nan, Y.H. Degradation and diversity changes of meadow grassland in Keerqin Sandy Land. *Atca Pratacult. Sin.* **2006**, *15*, 18–26.
27. Yan, Q.L.; Liu, Z.M.; Zhu, J.J.; Luo, Y.M.; Wang, H.M.; Jiang, D.M. Structure, pattern and mechanisms of formation of seed banks in sand dune systems in northeastern Inner Mongolia, China. *Plant Soil* **2005**, *277*, 175–184.
28. Funes, G.; Basconcelo, S.; Diaz, S.; Cabido, M. Edaphic patchiness influences grassland regeneration from the soil seed-bank in mountain grasslands of central Argentina. *Austral Ecol.* **2001**, *26*, 205–212. [CrossRef]
29. Levassor, C.; Ortega, M.; Peco, B. Seed bank dynamics of Mediterranean pastures subjected to mechanical disturbance. *J. Veg. Sci.* **1990**, *1*, 339–344. [CrossRef]
30. Sacande, M.; Berrahmouni, N. Community participation and ecological criteria for selecting species and restoring natural capital with native species in the Sahel. *Restor. Ecol.* **2016**. [CrossRef]
31. Tolvanen, A.; Laine, K. The alpine soil seed standing vegetation bank in relation to field seedlings and in subarctic Finland. *Arct. Antarct. Alp. Res.* **2004**, *36*, 229–238.
32. Bruno, B. Dispersal-limited species—A challenge for ecological restoration. *Basic Appl. Ecol.* **2014**, *15*, 559–564.
33. Amiaud, B.; Touzard, B. The relationships between soil seed bank, aboveground vegetation and disturbances in old embanked marshlands of Western France. *Flora* **2004**, *199*, 25–35. [CrossRef]
34. González-Alday, J.; Marrs, R.H.; Martínez-Ruiz, C. Soil seed bank formation during early revegetation after hydroseeding in reclaimed coal wastes. *Ecol. Eng.* **2009**, *35*, 1062–1069. [CrossRef]
35. Matus, G.; Papp, M.; Tothmeresz, B. Impact of management on vegetation dynamics and seed bank formation of inland dune grassland in Hungary. *Flora* **2005**, *200*, 296–306. [CrossRef]
36. Tessema, Z.K.; de Boer, W.F.; Baars, R.M.T.; Prins, H.H.T. Influence of grazing on soil seed banks determines the restoration potential of aboveground vegetation in a semi-arid savanna of Ethiopia. *Biotropica* **2012**, *44*, 211–219. [CrossRef]
37. Sun, J.H.; Wang, Y.R.; Zeng, Y.J. Characteristics of the soil seed banks in degenerated grasslands under grazing and grazing suspension. *Acta Bot. Boreali Occident. Sin.* **2005**, *25*, 2035–2042.
38. Tong, C.; Feng, X.; Zhang, Y.M.; Zhong, Y.K. Soil seed banks in different grazing exclusion restoring succession stages in the Xiligole degraded steppe. *Acta Ecol. Sin.* **2008**, *28*, 1991–2002.
39. Zhang, J.Y.; Wang, Y.; Zhao, X.; Zhang, T. Grassland recovery by protection from grazing in a semi-arid sandy region of northern China. *N. Z. J. Agric. Res.* **2005**, *48*, 277–284. [CrossRef]
40. Bai, F.; Settles, A.M. Imprinting in plants as a mechanism to generate seed phenotypic diversity. *Front. Plant Sci.* **2015**. [CrossRef] [PubMed]
41. Fernandez-Lugo, S.; de Nascimento, L.; Mellado, M.; Bermejo, L.A.; Arevalo, J.R. Vegetation change and chemical soil composition after 4 years of goat grazing exclusion in a Canary Islands pasture. *Agric. Ecosyst. Environ.* **2009**, *132*, 276–282. [CrossRef]
42. Gomaa, N.H. Soil seed bank in different habitats of the Eastern Desert of Egypt. *Saudi J. Biol. Sci.* **2012**, *19*, 211–220. [CrossRef] [PubMed]

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