Impacts of revegetation management modes on soil properties and vegetation ecological restoration in degraded sandy grassland in farming-pastoral ecotone

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Abstract: Focusing on the impact of various vegetation management modes on sandy grassland's soil property and vegetation ecological restoration of farming-pastoral ecotone, field surveys and lab analysis were conducted to study the correlation between the characteristics of soil properties and vegetation ecological restoration under four different vegetation management modes, i.e., unenclosed natural restoration, enclosed natural restoration, unenclosed artificial restoration and enclosed artificial restoration, which have a restoration history of 15 years in the southern edge of the degraded sandy land area of Mu Us Desert in Leilongwan Town, Hengshan County, Shaanxi Province. After 15 years of vegetation restoration, these four vegetation management modes all proved to be useful for improving the vegetation ecological restoration and the soil quality of the degraded sandy grassland not only by enhancing the aboveground vegetation height, coverage and biomass but also increasing the content of soil clay, organic matter, CEC, total nitrogen, available nutrient while reducing soil bulk density. The vegetation ecological restoration effect and soil quality under enclosed or artificial restoration management are better than those of unenclosed or natural restoration management; and the most satisfactory vegetation ecological restoration effects and soil quality can be achieved under the integration of enclosed and artificial restoration management. Severely degraded sandy grassland, during the vegetation restoration, would form an interactional coordinating relationship with the vegetation and soil properties. Vegetation properties as height, coverage and biomass have significant positive correlations with organic matter, CEC, total nitrogen and available nitrogen, phosphorus, and potassium contained in soil. Only the adoption of the strict enclosure system, implementation of aggressive artificial vegetation restoration measures and the realization of the regurgitation-feeding policy of industry towards husbandry can guarantee the gradual restoration of degraded sandy grassland in farming-pastoral ecotone, so that it can continue to play the role of ecological protective screen.

Keywords: vegetable ecological restoration, degraded sandy grassland, revegetation management modes, farming-pastoral ecotone, soil property, enclosed restoration system
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1 Introduction

Degraded sandy grassland is an important part of the desertification land of the farming-pastoral ecotone in northern China[1]. Vegetation restoration enables the aboveground vegetation community type of degraded sandy grassland to become enriched and complex, and then improves the production, biomass and species diversity[2,3] of vegetation to promote the recovery of the ecological system[4]. Meanwhile, the breeding of aboveground vegetation can accelerate the improvement of physical and chemical properties of sandy surface soil and its microbial properties, so that the harmonious breeding of vegetation and soil can be achieved, and the

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reversion of degraded sandy grassland can be promoted[3,5]. Vegetation management, a critical influence factor of the restoration effects of sandy grassland, impacts the community characteristics and biological diversity of the aboveground vegetation on the one hand[3] and influences the improvement of soil physical and chemical properties on the other hand[6]. Therefore, studies on the impact of various vegetation management modes on soil properties and vegetation ecological restoration can provide a basis for the rationality evaluation of vegetation restoration management measures and the development of scientific vegetation management modes.

China has paid great attention to the vegetation restoration of farming-pastoral ecotone in the past six decades and has made some achievements in Mu Us Sandy Land[7], Hulun Buir Sandy Land[8], Horqin Sandy Land[9], Hunshadake Sandy Land[10] and other grasslands and degraded rural regions. However, due to the complexity of regional geographical environment conditions, degradation mechanism and economic development, vegetation restoration effects are apparently influenced by vegetation management modes. Enclosure, the most commonly adopted management mode in vegetation restoration, governs and controls grassland desertification by enclosing and prohibiting inning and grazing[11]. Studies on restoration effects of degraded sandy grasslands in recent years can be mainly divided into two aspects: one is about the impacts of enclosure on the aboveground vegetation of grasslands, including researches on biological diversity, vegetation production and biomass improvement[3,4,6], and property studies involving vegetation succession and seed bank[13]; the other is about the impacts of enclosure on soil physical and chemical properties, microbes, water-salt movement, etc[11,12]. Artificially arisen vegetations, compared with the naturally restored ones, have more rapidly recovered ecological system, greater biomass and accelerated improvement of soil physical and chemical properties[14,15]. Thus as can be seen, the past studies, mainly focusing on the influence brought about by vegetation managements as enclosure and artificial restoration toward aboveground vegetation or soil physical and chemical properties alone, have developed few comprehensive research reports on their impacts on soil physical and chemical properties and vegetation ecological restoration or the relationship between them. In addition, more and more researches have shown that the existence of an interrelated, interactional and inter-constraint unified relationship between vegetation and soil is an essential basis of the evaluation of vegetation restoration effects[16].

This paper looks into the response characteristics shown in soil physical and chemical properties and vegetation ecological restoration of the severely degraded sandy grasslands in northern Shaanxi's farming-pastoral ecotone under different vegetation management modes as enclosure and artificial restoration, aiming at revealing the long-term impacts of different vegetation management modes on the soil-vegetation system of degraded sandy grasslands, so that a scientific basis for the people's further awareness of the significance of human activity in the restoration of the degraded ecological system can be provided, and some suggestions and recommendations on the vegetation restoration management of farming-pastoral ecotone can been proposed.

2 Materials and methods

2.1 Research area

The farming-pastoral ecotone locates in northern Shaanxi Province and on the zone of transition between two major natural regions: Mu Us Sandy Land and Loess Plateau. The northern and southern parts of the zone are wind and water erosion regions respectively, and strong features of transition are manifested in the ecological environment. The landform here changes from loess gully and loess ridge to sandy beach from the southeast to the northwest. The arid and semi-arid inland climate maintains an annual mean temperature of 7-9℃ here. The zone has a short frost-free season and 300-500 mm precipitation amount, of which most occurs in July to September. The vegetation transmits from forest in the southeast to the dry steppe and desert steppe in the northwest. The agricultural industry consists mainly of farming and animal husbandry. In agriculture, the most regular crop is corn, while in animal husbandry sheep is the most common livestock. The target degraded grasslands, mostly distributing in the northwest and particularly in the northern part of Hengshan County and Jingbian County, is the zone of transition from the Erdos Grassland to the Loess Plateau with typical sandstorm grasslands. The wind erosion is strong here and the sandy lands are in a continuous distribution.

2.2 Sample plot setting

The prevention and control against the desertification of degraded grasslands in farming-pastoral ecotone of northern Shaanxi, in response to the Western Development of China and the Grain for Green project, had not been performed until lately. Nevertheless, after a decade of efforts, certain achievements have been made in the prevention and control against the desertification of the degraded grasslands within the zone. Leilongwan Township of Hengshang County, a particularly outstanding region, has more than 4 500 hm^2 of forests planted on the former deserted sandy lands and a vegetation coverage ratio up to 40%. As a result, this study selected this restored vegetation protection zone as a sample setting plot. According to the result of interviews and surveys conducted in this area in July 2012, the protection zone with a 15-year restoration age that locates in the southwest of the township was selected as the sample setting region. Under the instruction of local guides, the regions under four different management modes were set as the sample plots, i.e., the unenclosed natural restoration zone, enclosed natural restoration zone, unenclosed artificial restoration zone and enclosed artificial restoration zone. Meanwhile, certain mobile dunes without any vegetation restoration were chosen as comparable plots. The basic conditions of the sampling plots are as shown in Table 1.

Table 1 Characteristics of sample sites in the farming-pastoral ecotone

Management mode	Restoration year	Altitude/m	Longitude (E)	Latitude (N)	Slop/(°)	Plant species
Unenclosed natural restoration	16	1169	109°05'15″	37°59'04″	7-10	*Artemisia desertorum, AgriopHyllum squarrosum,*
Enclosed natural restoration	15	1166	109°05'16″	37°59'08″	10-13	*Artemisia desertorum, AgriopHyllum squarrosum, Agropyron cristatum*
Unenclosed artificial restoration	15	1168	109°05'18″	37°59'14″	6-9	*HippopHae rhamnoides L, Caragana Korshinskii, AgriopHyllum squarrosum*
Enclosed artificial restoration	14	1165	109°05'06″	37°59'18″	9-12	*AmorpHa fruticosa, Caragana Korshinskii, Haloxylon persicum*
Mobile dune	0	1170	109°05'22″	37°59'26″	6-9	*Artemisia desertorum*

2.3 Sample collection and analysis

Three 3 m × 3 m sampling squares were respectively set in the sampling plots under different management modes, and five sampling points were taken from each sampling square. Soil samples were collected separately from each sampling square with the genetic method according to the color and texture of the upper and lower layers of the observation sediments, and 1 kg of soil samples was collected from each layer and put into soil bags. The soil samples were naturally dried and sieved through a 2 mm sieve when brought back to the lab, of which some were provided for the analysis of soil mechanical composition and the rest were further levigated for the study of soil chemical property. Soil bulk density and porosity were collected from the same layers and tested (for three repeated times) with the cutting-ring method. While soil samples were collected from each sampling square, the basic vegetation characteristics were inspected, such as vegetation type, quantity, height and coverage; the samples were meanwhile processed with oven drying method to determine the aboveground biomass.

Methods and ways as follows were adopted: cutting-ring method for soil bulk density; porosity calculation based on volume weight of soil; hydrometer method for soil particle composition; pH meter for pH value testing (ratio of soil to water: 1:2.5); potassium dichromate method-oxidation and external heating for organic content determination; Kjeldahl method for total nitrogen determination; acid accumulator bath-Mo-Sb colorimetric method for total phosphorus determination; perchloric acid-sulfuric acid resolution for total potassium determination; $NaHCO_3$ digestion and Mo-Sb colorimetric method for rapid available phosphorus determination; NH_4OAc digestion and photometry for rapid available phosphorus determination; ammonium acetate exchange process for CEC. All these analytical methods were used under the instruction of Soil Agrochemistry Analytical Methods[18].

2.4 Data processing

AVONA analysis was used for the significance test of differences of vegetations and soil chemical and physical properties under various management modes. The statistical package of Excel and SPSS19.0 was used to analyze the acquired data.

3 Results

3.1 Impacts of vegetation management modes on vegetation ecological restoration

Essential features of the severely degraded sandy grasslands, such as the vegetation height, density, coverage and biomass (Table 2), have been remarkably improved with the vegetation restoration. Compared with the mobile dune, under the various management modes, the vegetation height, coverage and biomass have respectively increased by 0.12-1.03 m, 12.7%-53.0% and 7.3-29.1 g/m^2. These essential vegetation features vary significantly under different management modes (p<0.05). Relevant data of the artificially arisen vegetation, except the vegetation density, is remarkably higher than the naturally restored, and the same data of vegetation arisen under enclosed conditions is remarkably higher than unenclosed. As for vegetation density, natural restored vegetation is higher than the artificially restored. This is mainly because that, generally, natural restoration uses herbaceous vegetations and artificial restoration uses shrubby vegetation. The results proved that enclosure reduces livestock's grazing and tread on vegetation, and artificial restoration measures accelerate the development of shifting sandy grassland's simple community structure toward the complex, thus guaranteeing a protection for vegetation restoration.

Table 2 Plant characteristics in different revegetation management modes

Management mode	Height /m	Density /number/m^2	Coverage /%	Biomass /g·m^{-2}
Unenclosed natural restoration	0.37±0.27d	12±6b	19.2±6.8d	21.8±7.3d
Enclosed natural restoration	0.49±0.28c	22±9a	36.2±11.9c	29.5±9.4c
Unenclosed artificial restoration	0.92±0.45b	6±4d	44.7±24.3b	36.7±16.4b
Enclosed artificial restoration	1.28±0.61a	9±6c	58.5±34.6a	43.6±24.3a
Mobile dune	0.25±0.14e	0.4±0.05e	6.5±2.4e	14.5±5.8e

Note: Different letters in each row indicate significant differences (p<0.05).

3.2 Impacts of vegetation management modes on soil physical properties

Though it has been 15 years since the vegetation restoration began to be managed under enclosure and artificial restoration, no significant change has been shown in the content of sand, silt or clay of the soil. Nevertheless, soil bulk density has been remarkably reduced, while the porosity has been signally improved (Table 3).

Table 3 Soil physical characteristics in different revegetation management modes

Management mode	Layer /cm	Soil Texture/%			Bulk Density /g·cm^{-3}	Total Porosity /%
		Sand (2-0.02 mm)	Silt (0.02-0.002 mm)	Clay (<0.002 mm)		
Unenclosed natural restoration	0-10	83.41±12.28a	9.87±3.22a	6.72±2.26ab	1.47±0.36c	43.32±12.24c
	10-30	89.68±14.31a	4.62±1.25 ab	5.70±2.41ab	1.57±0.42a	38.39±7.82d
Enclosed natural restoration	0-8	83.79±16.29a	8.47±2.26a	7.74±2.75a	1.46±0.37c	44.34±10.34c
	8-30	87.67±14.36a	5.22±1.67 ab	7.11±2.69a	1.53±0.47ab	36.25±9.69d
Unenclosed artificial restoration	0-4	82.14±12.24a	7.88±2.63a	9.98±2.69a	1.40±0.54d	48.57±13.53b
	4-30	89.98±17.62a	3.71±1.47 ab	6.31±1.75ab	1.57±0.63a	37.38±11.47d
Enclosed artificial restoration	0-7	71.81±9.72ab	16.88±4.36a	11.31±3.25a	1.32±0.46e	53.54±12.28a
	7-30	84.62±11.06a	6.44±2.24a	8.94±2.14a	1.52±0.76b	38.61±10.29d
Mobile dune	0-10	92.91±18.37a	3.61±0.85ab	3.48 ±0.78ab	1.59±0.48a	36.53±7.86d
	10-30	93.91±22.46a	2.61±1.02ab	3.48±1.17ab	1.61±0.61a	37.42±9.27d

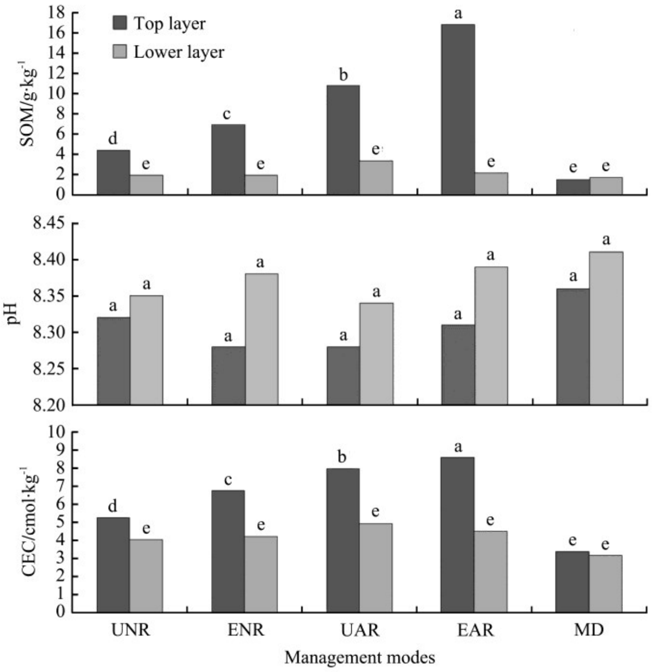
Note: Different letters in each row indicate significant differences (p<0.05).

The variation of the lower layer soil, on the contrary, is not that obvious. Compared with the shifting sandy land, both the top layer and lower layer soil, under different vegetation management, have slightly lowered sand grain content and raised clay content-the variation is not notable, though, nor the difference is significant under diverse management modes (p>0.05). Compared with the mobile dune, soil bulk density under different vegetation restoration management modes has reduced by 0.12-0.27 g/cm, and the total porosity has increased by

5%-17%, both soil bulk density and total porosity, under different vegetation management, have shown notable variations: the reduction range of volume weight of soil under enclosed mode or artificial restoration mode is slightly higher than under unenclosed mode or natural restoration mode respectively. The total soil porosity is in the opposite trend. Both the minimum soil bulk density (1.32 g/cm) and maximum total soil porosity (53.54%) occur under the enclosed artificial restoration mode.

3.3 Impact of vegetation management modes on soil organic matter, pH value and CEC

Soil organic matter is the primary manifestation of quality of soil with restored vegetation. It can be seen from Figure 1 that compared with the mobile dune, the soil organic contents under different management modes have all been remarkably improved within a range of 3-15 g/kg after 15 years of vegetation restoration, but the variation of the lower layer soil is not obvious. Of all these varied management modes, the organic content under artificial vegetation restoration is 40%-150% higher than that under natural vegetation restoration, and it is markedly higher under enclosed management than under unenclosed management.



Note: UNR means unenclosed natural restoration, ENR means enclosed natural restoration, UAR means unenclosed artificial restoration, EAR means enclosure artificial restoration, MD means mobile dune. Significant interactions were at a=5%. Different letters on the bar indicate significant differences. Same below.

Figure 1 Soil organic matter, pH value and CEC in different revegetation management modes

Compared with the shifting sandy land, after 15 years of vegetation restoration, there is no significant variation of soil pH value either in different soil layers or under varied management modes. Soil pH value maintains between 8.25-8.45, indicating that vegetation restoration does not significantly influence soil pH value. Soil CEC, on the other hand, follows the same trends as soil organic content (Figure 1). After 15 years of vegetation restoration, soil CEC, compared with the mobile dune, has improved by 2.5-6.4 cmol/kg under different management modes, 1.5-3.6 cmol/kg higher in artificial vegetation restoration than in natural vegetation restoration and 1.3-2.6 cmol/kg higher under enclosed mode than under unenclosed mode.

3.4 Impact of varied vegetation management modes on soil nutrients

Figure 2 shows that the variation trend of soil nitrogen is similar to soil organic matter. The mobile dune has shown a remarkable increase in soil nitrogen content after the vegetation restoration. The variation is visibly different under varied management modes. The maximum total nitrogen and available nitrogen reaches 0.63 g/kg and 26 mg/kg respectively under the enclosed artificial vegetation restoration management, followed by the unenclosed artificial restoration mode; and the minimum contents occur under the unenclosed natural vegetation restoration.

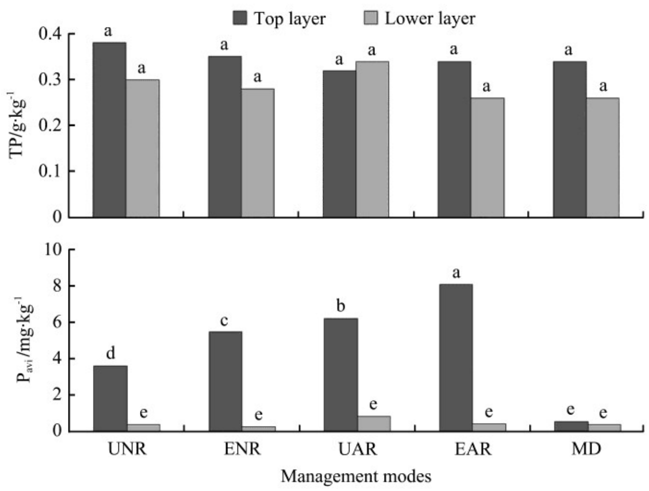


Figure 2 Soil total and available nitrogen in different revegetation management modes

Figure 3 and Figure 4 suggest that, vegetation restoration and diverse management modes have no obvious impact on soil total phosphorus and total potassium,

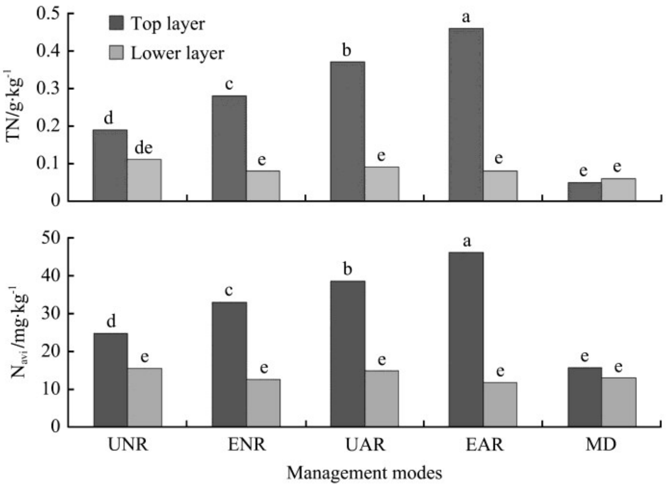


Figure 3 Soil total and available phosphorus in different revegetation management modes

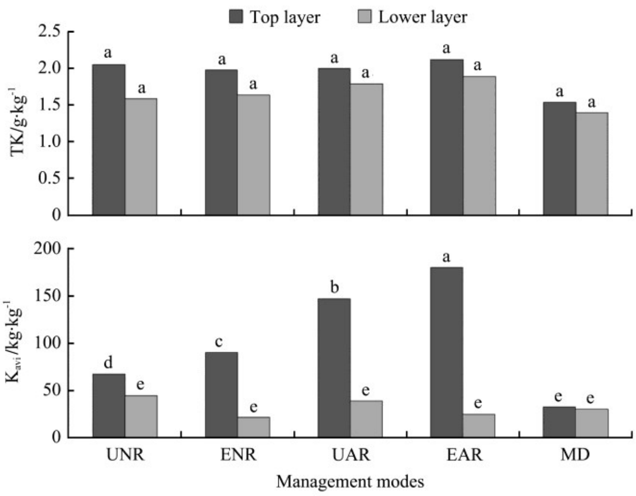


Figure 4 Soil total and available potassium in different revegetation management modes

but they have a remarkable influence on soil available phosphorus and available potassium. Vegetation restoration can significantly improve the content of soil available phosphorus and potassium. The sequence of such contents under different modes from low to high is: unenclosed natural restoration < enclosed natural restoration < unenclosed artificial restoration < enclosed artificial restoration.

3.5 Correlation between vegetation and soil properties

The relevant analysis suggests that the research area has shown a close relationship between the vegetation characteristics and soil physical and chemical properties after the management of enclosure and artificial vegetation restoration. The vegetation height, coverage and biomass present a significant positive correlation relationship with the soil porosity, organic matter, CEC, as well as the total nitrogen and available nitrogen, phosphorus and potassium, but a significantly negative correlation relationship with soil bulk density (as shown in Table 4).

Table 4 Correlation between plant characteristics and soil characteristics

Items	Sand	Silt	Clay	BD	P_t	SOM	TN	TP	TK	Av-N	Av-P	Av-K
Height	-0.103	0.245	0.354	-0.523^{*}	0.547^{*}	0.826^{**}	0.742^{**}	0.124	0.227	0.754^{**}	0.695^{**}	0.653^{**}
Coverage	-0.097	0.312	0.431	-0.713^{**}	0.436	0.793^{**}	0.815^{**}	0.158	0.083	0.548^{*}	0.736^{**}	0.731^{**}
Biomass	-0.135	0.141	0.262	-0.552^{*}	0.475	0.751^{**}	0.749^{**}	0.052	0.157	0.893^{**}	0.357	0.359

Note: * $p<0.05$, ** $p<0.01$, BD means bulk density, Pt means total porosity, SOM means soil organic matter, TN means total nitrogen, TP means total phosphorus, TK means total potassium, Av-N means available nitrogen, Av-P means available phosphorus, Av-K means total potassium.

Since the variation of soil particle composition, total phosphorus and potassium is quite small in the short run, their correlation relationship with the vegetation properties is not remarkable.

4 Discussion

4.1 Impact of vegetation management modes on vegetation ecological restoration

The vegetation restoration of degraded sandy grasslands can remarkably promote the positive evolution of vegetation and influence the vegetation diversity and community characteristics[16]. Survey findings of this paper have shown that the vegetation diversity and community characteristics of regions with restored vegetation have been remarkably improved and transmitted gradually from the desert to the grassland and shrub land vegetation characteristics. Some grassland vegetations as wheatgrass and shrubby vegetations as caragana microphylla, sea-buckthorn and amorpha fruticosa reappear in vegetation restoring areas, and the height, coverage and density of vegetations have all remarkably improved, indicating that these vegetations adapt the dry, rainless and soil depletion desert climate in farming-pastoral ecotone. Wang et al.[3] have come to similar conclusions. Vegetation diversity and community characteristics vary under different vegetation management modes. Vegetation characteristics under enclosed or artificial restoration mode are superior to those under unenclosed or natural restoration mode. The most diverse species and the highest coverage, height and biomass occur under the enclosed artificial vegetation management, mainly because strict enclosure measures can notably reduce livestock and human's grazing and tread on vegetation[19] and artificial restoration measures can promote the upgrading of the simple community structure[20] of the aboveground of the severely degraded sandy grassland to a complex grass-shrub structure, and thus offer protection to the restoration of the degraded sandy grassland.

4.2 Impacts of vegetation management modes on soil physical and chemical properties

Despite the fact that vegetation restoration can significantly improve the soil physical and chemical properties of the severely degraded grassland, it is notably affected by the modes of vegetation management. The results of this study suggest that soil bulk density of the severely degraded sandy grassland declines remarkably after vegetation restoration, while the total porosity, soil organic matter and nutrient content significantly improve. Su et al. [6] and Wen et al.[19] have reached similar conclusions. There might be two causes for it: firstly, with the increase of aboveground vegetation biomass, ingredient amount returned to the soil improves. The weaving, squeezing and segmenting enforced by plant root systems on the soil contribute to the decrease of soil bulk density and improvement of soil total porosity, while the organic matters and root exudates produced by the dead root systems, dry branches and fallen leaves can markedly improve the content of soil organic matters and nutrients[21-23]. Secondly, with the gradual increase of the aboveground vegetation coverage in the restoration, wine erosion and its strength gradually decline and a large amount of wind erosion fine particles and dust falls will enter the surface layer of soil after being intercepted and captured[19], and thus the aboveground fine particulate matters and the porosity are comparatively increased and soil bulk density is comparatively reduced[24,25]. Among the various vegetation management modes, the soil total porosity, organic matters, CEC and nutrient content are higher under enclosed than unenclosed conditions, mainly because enclosure reduces human disturbance, promotes vegetation ecological restoration, decreases wind erosion and stops the loss of soil fine particles and nutrients[3]. On the other hand, the soil physical and chemical properties under artificial restoration management are superior to under natural vegetation, mainly because the major plant adopted by the artificial restoration management is shrubby vegetation, which, compared with the grassland vegetation, has bigger plant, more developed root system, higher leakproofness, larger biomass and more returned dry branches and fallen leaves to the soil, and these properties are beneficial to the soil nutrient accumulation. Meanwhile, caragana microphylla and amorpha fruticosa are leguminosae, and they can lock up nutrients.

4.3 Correlation between vegetation and soil during the vegetation restoration of sandy grassland

Ecology and soil science theory and ecological construction projects have proved that the effects of ecological restoration and rebuilding on severely degraded vegetation system depend on the soil forming, developing and quality status, as well as the mutual promotion and coordination relationship between the soil and plants[26,27]. Therefore, the coordination between soil and plants can be used for evaluating the rationality of vegetation restoration management measures[28]. Findings of this research have shown that vegetation and soil form an interactional and interrelated coordinating relationship during the vegetation process of severely degraded grasslands, and after the enclosure, artificial vegetation restoration and other management measures are taken[20,29,30]. Soil organic matters, CEC, total nitrogen and available nitrogen, phosphorus, and potassium are in a significantly (p<0.05) positive correlation relationship with vegetation height, coverage and biomass, while the soil bulk density is in a significantly (p<0.05) negative correlation relationship with vegetation height, coverage and biomass. The aboveground vegetation restoration of the desert ecosystem improves the soil quality, which further provides nutritive substance for vegetation growth, promoting the gradual forming of an interacting sound recycling system between the vegetation and soil. As a result, research areas should insist on following the vegetation restoration management mode that integrates enclosure and artificial restoration, and positive artificial vegetation restoration measures should be taken to manage the degraded grassland.

5 Conclusions and suggestions

Vegetation rebuilding is the primary way to improve the soil quality of degraded ecological system. Through the analysis and comparison of the vegetation ecological restoration effects gained 15 years after four kinds of vegetation community management measures were taken, it has been found that vegetation improves the soil clay, organic matters, CEC, total nitrogen and rapidly available nutrient content and reduces the volume weight of soil at varying degrees while improving the soil quality of the degraded sandy grassland of farming-pastoral ecotone, promoting the ecological restoration of vegetation and enhancing the aboveground vegetation coverage and biomass. The improvement of soil quality and vegetation under enclosed and artificial vegetation restoration management mode is more obvious than unenclosed and natural vegetation restoration. Under this management mode, soil and vegetation can form an interacting sound recycling system and the coordinative development of them can be achieved. Meanwhile, the mechanism of the improvement of desertification ecosystem through vegetation restoration is the optimizing of vegetation breeding and soil properties. Monitoring and analyzing of the variation of soil and vegetation properties and their mutual relation is the base of the evaluation of effects obtained through vegetation restoration and the ground of selecting the scientific and rational vegetation restoration measures.

As the local animal husbandry base and the ecological protective screen, sandy grassland will continue to create economic and ecological value to the farming-pastoral ecotone of northern Shaanxi Province. However, the severe degradation trend of sandy grasslands is weakening such value, and the protection and operation level of management sections toward degraded grasslands will directly influence the future function level of sandy grasslands. To reinforce sandy grassland's role of ecological protective screen, three factors must be stressed. Firstly, strict enclosure system must be implemented to eliminate all excessive external pressures, e.g., overgrazing, land abandonment during reclamation and excessive digging. Secondly, breeding of artificial vegetation should be aggressively performed, vegetation restoration protection zone must be established and long-term ecological restoration management schemes shall be carried out. Thirdly, with the exploitation of the large amounts of mineral resources in the farming-pastoral ecotone of northern Shaanxi Province, the regurgitation-feeding of industry toward animal husbandry becomes necessary. Meanwhile, husbandry's pressure on sandy grasslands should be reduced and ranch farmers should be appropriately subsidized. Only through these measures can the succession of degraded sandy grassland be restored, so that its role of ecological protective screen can be played continuously.

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