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Impacts of Different Types of Vegetation Restoration on the Physicochemical Properties of Sandy Soil

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Abstract: Understanding the integrated effects of vegetation types on the physicochemical properties and quality of sandy soils is crucial for guiding vegetation reconstruction and ecological restoration in desertified areas. This study selected three vegetation types at the southern edge of the Mu Us sandy land, including fenced *Leymus secalinus* Turcz. grassland (LS), natural *Hedysarum mongolicum* Turcz (HM) forest land, and *Salix cheilophila* Schneid. (SC) forest land, as well as sandy land as a control (SD). The differences in the soil physicochemical properties were investigated by collecting soils from three layers within 0–60 cm. The soil quality index (SQI) was calculated using principal component analysis to comprehensively evaluate the soil quality. This study found that the soil physicochemical properties differed significantly among the plots and layers, and the soil properties exhibited a vertical distribution, with chemical indicators concentrated in the surface layer. As depth increased, differences in soil properties between the vegetation and control plots diminished, with vegetation influence mainly in the 0–20 cm layer. Among all the sample sites, the 0–20 cm layer of LS had the highest organic matter content (5.98 g/kg), which was 2.25, 2.28, and 4.71 times that of HM, SC, and SD, respectively. Moreover, LS had the lowest bulk density (1.35 g/cm³), which was 0.89, 0.91, and 0.86 times lower than that of HM, SC, and SD, respectively. The effects of different vegetation restoration types on the comprehensive quality of soil were different, as shown in LS (0.15) > HM (0.11) > SC (0.10) > SD (0.08). In conclusion, all three vegetation restoration types significantly affected the soil physicochemical properties and led to different degrees of variability of soil indexes in the vertical profile, and the fenced grassland restoration type may be preferable for ecological restoration and reconstruction in this region.

Keywords: desertification; vegetation restoration types; soil physicochemical properties; soil quality index; Mu Us sandy land



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1. Introduction

Desertification, a form of land degradation that predominantly occurs in arid and semi-arid regions, is characterized by wind and sand activities as a result of unsustainable interactions between humans and the land. It stands as one of the most pressing environmental challenges confronting both the global community and, specifically, China [1].

Studies across different regions have demonstrated that vegetation restoration can significantly improve soil quality [2], nutrients [3], and microbial activity [4]. It reduces soil bulk density, enhances aggregate stability, and increases the soil water-holding capacity and infiltration performance by boosting inputs of surface litter and below-ground organic matter such as fine roots and root secretions [5]. Many studies have examined changes in soil physicochemical properties following vegetation restoration in China, such as in the Loess Plateau region [6], the karst region of southwest China [7], and the Tibetan Plateau

region [8]. Research findings from southern Brazil have also demonstrated the role of vegetation. Compared to native grasslands, traditional croplands have significantly lower soil water stability, while sandy lands completely lack soil water stability. Furthermore, sandy lands have the lowest SOC, making them more susceptible to wind erosion and soil degradation [9].

The change in soil properties in the process of vegetation succession is also a focus of attention. A chronology study of semi-arid abandoned lands in the central Loess Plateau in China showed that over the past 150 years, the surface layer (0–20 cm) bulk density has significantly decreased over time, while the soil porosity, water-holding capacity, aggregate stability, and SOC content have all significantly increased [10].

As one of the China's four major sandy lands, the Mu Us sandy land is plagued by strong winds and moving sands, which have long-affected residents' production and livelihoods. To improve the environment, the local government has implemented a series of ecological restoration and vegetation construction projects over the years, including artificial afforestation, aerial-seeding afforestation, sand-fixation afforestation, and grass planting, as well as "Grain for Green" projects [11]. Fencing is the most effective common restoration measure in this region, influencing both the composition of plant communities and the soil properties. After fencing, the natural vegetation succession in the area is as follows: annual herbaceous short-lived pioneer plants, annual biennial herbs, perennial herbs, half shrubs, and perennial shrubs. Although plowing can increase biodiversity and improve community evenness, its effect is not significant [12]. Fencing measures also can increase the quantity and variety of seeds in the sandy soil [13]. In terms of soil properties, after 7, 10, 13, and 20 years of fencing in degraded grasslands, the soil BD of the 0–30 cm layer significantly decreases, and the porosity significantly increases [14]. Chen et al. [15] found that with increasing sandification, soil physicochemical properties declined while pH increased. Chang [16] concluded that implementing the "Grain for Green" project in the desert steppe area of Ningxia, compared to in natural grasslands, significantly increased the soil organic carbon content in returned croplands.

In summary, most current domestic and international studies have primarily focused on the changes in biodiversity and the effects on various physicochemical properties of soils following different vegetation restoration efforts in the Mu Us sandy land. However, the comprehensive evaluation of different vegetation types on the quality of sandy soil by combining the many different properties of sandy soil has rarely been involved.

Reversing degraded sandy ecosystems and restoring their productivity is a key issue needing urgent solutions in current ecological environment construction. Returning farmland to forest and grassland is the main way to restore and rebuild degraded sandy grassland ecosystems. This is achieved by consciously regulating the relationship between herbivores, human activities, and plants in degraded ecosystems. Both small-scale experiments and large-scale remote sensing observations in countries such as Thailand [17], Iraq [18], and China [19] have unequivocally highlighted the critical role of vegetation restoration in combatting soil desertification. An important indicator of desertification is soil properties [20].

This study was conducted in the arid windy sand area of Yanchi County, located in the Mu Us sandy land of Ningxia. It aimed to analyze and understand the physicochemical properties of sandy soils under three vegetation restoration types: fenced grassland, natural forest lands, and mobile sand land. The research was primarily focused on establishing the differential impacts of various management strategies on the restoration of the degraded sandy soil vegetation system. The study intended to furnish a scientifically grounded framework for selecting efficient and logical vegetation restoration methods in the region, thereby assisting in the process of ecological restoration and reconstruction.

2. Materials and Methods

2.1. Study Area

The study area was situated in Shaquanwan, Yanchi County, Ningxia Province, nestled on the southwestern fringe of the Mu Us sandy land at an elevation ranging from 1560 to 1618 m [21], characterized by a typical temperate continental monsoon climate. The land use within the area signified a transition from agricultural to pastoral zones. The region received an annual precipitation of 250 to 350 mm, primarily concentrated in the months of July, August, and September, accompanied by a high evaporation rate of up to 2170 mm. Exhibiting an annual average temperature of 7.7 °C, an average wind speed of 2.8 m/s, and an average relative humidity of 51%, the frost-free period extended for 128 days. The prevailing soil type in the study area was aeolian sandy soil, which was defined by its loose structure and relatively low fertility, while the natural vegetation predominantly consisted of psammophytic plants, such as *Leymus secalinus* Tzvel., *Salix cheilophila* Schneid., *Artemisia scoparia* Waldst. et Kit., *Caragana intermedia* Kuang et H. C. Fu., and *Hedysarum mongolicum* Turcz. [22].

2.2. Experimental Design and Soil Sampling

In this study, three types of plots were selected, including fenced *Leymus secalinus* Tzvel. grassland (LS), which has been restored for 5–8 years, as well as natural *Hedysarum mongolicum* Turcz. (HM) forest land of the primary local tree species and *Salix cheilophila* Schneid. (SC) forest land, both of which were young forests with an age of 5–8 years. Sandy land was used as a control (SD). In each of the four types of plots, three representative replicates were chosen for investigation. The basic information for these plots can be found in Table 1. The size of SD and LS was 1 m × 1 m, and that of HM and SC was 10 m × 10 m. Field sampling took place from 20–24 July 2015 during a stretch of sunny and rain-free weather. In the LS plots, LS consistently emerged as the dominant species, exceeding a coverage of 50%. Additionally, Table 1 itemizes other significant herbaceous species found within these plots. In their respective plots, both HM and SC were identified as the sole dominant tree species. The primary herbaceous species residing in the understories of these forests are also enumerated in Table 1.

Table 1. Status of different vegetation types.

Stand	Canopy Density (%)	Underground Coverage (%)	Spacing (m)	Breast-Height Diameter (cm)	Main Plant Species of the Vegetation Composition
SD	NA	NA	NA	NA	NA
LS	NA	60	NA	NA	<i>Artemisia desertorum</i> Spreng., <i>Agriophum pungens</i> (Pall.) Moq.
HM	60	30	2 × 2	7	<i>Cynanchum mongolicum</i> Maxim.; <i>Artemisia desertorum</i> Spreng.
SC	60	35	2 × 2	7	<i>Calamagrostis epigeios</i> (L.) Roth; <i>Cynanchum mongolicum</i> Maxim.

Note: SD: Sandy land; LS: *Leymus secalinus* Tzvel.; HM: *Hedysarum mongolicum* Turcz.; SC: *Salix cheilophila* Schneid. NA, not applicable. The same for the below tables and figures.

In each plot, soil samples were collected at four locations at depths of 0–20, 20–40, and 40–60 cm. Soil samples were collected using a small aluminum box (46 mm in diameter × 25 mm in height), and their wet weight was measured. Upon transport to the laboratory, the samples were placed in a drying oven at 105 °C and dried to a constant weight to determine the natural soil moisture content. Undisturbed soil was extracted using a ring cutter (100 cm³ stainless steel cylinder). Additional soil samples were collected in zip-lock bags, air-dried, and stored at room temperature for analysis of other soil chemical properties. At least three soil samples were collected from each layer in the profile.

2.3. Determination of Soil Physical and Chemical Properties

Soil natural water content (SNW) was determined by the drying method. Soil bulk density (BD), saturated moisture content (SMC), capillary moisture content (CMC), total porosity (TPO), and capillary porosity (CPO) were determined by ring sampler method. Soil pH was measured by acidimeter, soil organic matter (SOM) was determined by the $K_2Cr_2O_7$ wet oxidation method [23], soil total nitrogen (TN) was determined by the Semimicro-Kjeldahl method (Foss KJELTEC0303, Kjeldahl Apparatus, Hillerød, Denmark), total phosphorus (TP) was determined by the Mo-Sb Sepetrochrometry method (Thermo ice3000, Spectrophotometer, Waltham, MA, USA), and total potassium (TK) was determined by the flame photometric method (Sherwood M410, Flame Photometer, Cambridge, UK). The specific determination methods of the above soil properties can be found in the references [24,25].

2.4. Statistical Analysis

A single soil index was not sufficient to accurately and intuitively illustrate the variations in soil properties, and it was necessary to synthesize a variety of indexes. However, some of the selected indices had a significant correlation with each other, necessitating a reduction in the number of indices. The soil quality index (SQI) method was an excellent comprehensive evaluation method, and it had been widely applied in soil quality evaluations [26]. In this study, the SQI was selected as a comprehensive evaluation index. The evaluation method mainly included the following steps:

- (1) Soil indicators with a large contribution in each principal component were selected through principal component analysis (PCA). If a principal component contained multiple indicators with substantial contributions, the indicators with a weak correlation were identified using correlation analysis [27];
- (2) The chosen indicators were standardized according to Equations (1) and (2) [28];
- (3) The SQI was then calculated in line with Equation (3) [29].

$$S = \frac{X - m}{M - m}, \quad (1)$$

$$S = 1 - \frac{X - m}{M - m}, \quad (2)$$

where S represents the standardized indicator value (0~1), X is the measured indicator value, m denotes the lowest indicator value, and M is the maximum indicator value. If the principle “the bigger the better” applies to the indicator, Equation (1) should be selected for standardization. Conversely, when the indicator is “the smaller the better”, then Equation (2) should be chosen.

$$SQI = \sum_{n=1}^n W_i \cdot S_i \quad (3)$$

where W_i is the weight of the i th factor; S_i is the standardized indicator value, and n is the number of participating indicators.

Excel 2019 was used for data processing. A one-way ANOVA in SPSS19 was used to examine the differences of soil indexes in the same soil layer and different soil layers under the same vegetation type ($p < 0.05$). Principal component analysis was used to analyze the effects of different vegetation restoration types on SQI.

3. Results

3.1. Soil Physical Properties under Different Vegetation Types

As illustrated in Figure 1a, across diverse vegetation recovery types, soil bulk density (BD) was found to progressively increase with the depth of the soil layer. The impact of vegetation on reducing BD was more pronounced, particularly in the top 0–20 cm depth, where the BD of plots with vegetation cover was lower than that of sandy land (SD). The

average BD of LS in the 0–60 cm depth was the smallest, indicating that the soil in LS was the most porous. In the 0–40 cm soil layer, the BD of both HM and SC was slightly less than that of SD, but it was opposite in 40–60 cm. However, no significant difference in BD between the two forest lands at each layer was observed ($p > 0.05$).

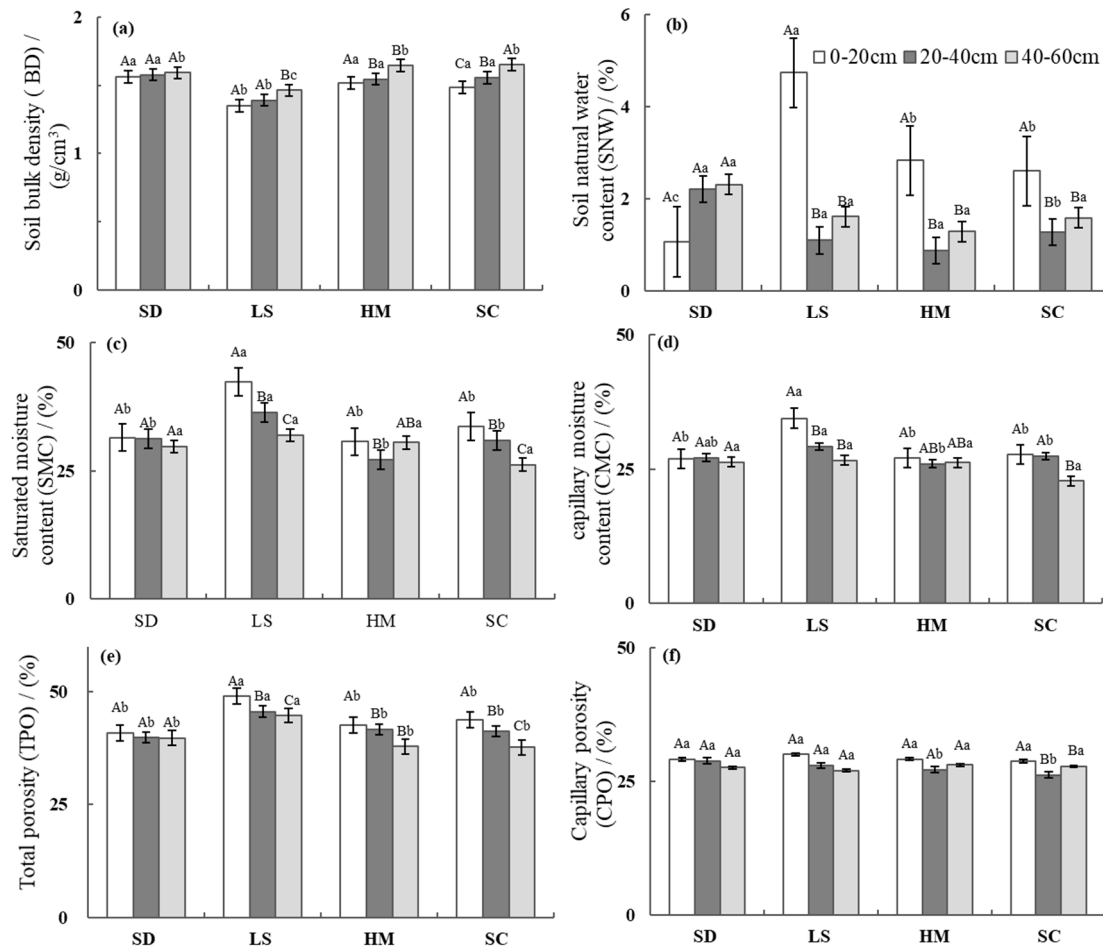


Figure 1. Soil physical properties under different vegetation restoration patterns ((a) Differences in soil bulk density (BD) under different vegetation types and soil layers; (b) Differences in soil natural water content (SNW) under different vegetation types and soil layers; (c) Differences in soil saturated moisture content (SMC) under different vegetation types and soil layers; (d) Differences in soil capillary moisture content (CMC) under different vegetation types and soil layers; (e) Differences in soil total porosity (TPO) under different vegetation types and soil layers; (f) Differences in soil capillary porosity (CPO) under different vegetation types and soil layers). Different lowercase letters indicate significant differences ($p < 0.05$) between different communities in the same soil layer. Different capital letters indicate significant differences ($p < 0.05$) between different soil layers in the same community. The data in the brackets are the standard deviations (SD).

Soil water-holding conditions under different vegetation covers are illustrated in Figure 1b–d, in which the SNW, SMC, and CMC of the four sampling plots decreased gradually with the increase in the soil layers. Concerning the vegetation types, the SNW values of LS, HM, and SC within 0–20 cm were significantly higher than that of SD, registering 4.5, 2.7, and 2.4 times higher than SD, respectively. The SMC of LS within 0–20 cm was 1.4, 1.3, and 1.3 times higher than that of HM, SC, and SD, respectively, while the CMC of LS was 1.3, 1.2, and 1.3 times higher than that of HM, SC, and SD, displaying a significant difference ($p < 0.05$). Between the two forest lands, from 0–40 cm, the CMC of SC was slightly higher than that of HM. The minimum value of CMC appeared at 40–60 cm in SC. For the other soil layers, no substantial difference was observed among the four

sampling sites. This can be primarily attributed to the fact that LS exhibited a higher surface cover, which demonstrated a stronger water interception effect in conjunction with a smaller, partially exposed surface and diminished evapotranspiration, resulting in a higher soil water content. In contrast, forests displayed a lower degree of degradation, and the understory vegetation was not vigorous (Table 1), rendering the differences between the SMC and CMC of HM and SC lands and those of SD land not significant.

The soil porosities under different vegetation covers are shown in Figure 1e,f. With the deepening of the soil layer, the TPO of the four sample sites decreased significantly, while the CPO also declined gradually, though the differences among layers were not significant. In terms of vegetation types, the TPO of LS was significantly larger than that of the other samples in all soil layers, especially in 0–20 cm, where the TPO of LS was 1.1, 1.1, and 1.2 times higher than that of the other sites (HM, SC, and SD), respectively. The TPO of SC in the 0–20 cm soil layer was slightly higher than that of HM and SD. However, the differences between the TPO values of HM, SC, and SD in the soil layers were basically insignificant ($p > 0.05$). The largest CPO among the four sample plots was observed in the 0–20 cm layer of LS, although no significant difference in CPO was found among the soil layers in each sample site. This indicated that LS grassland can more effectively enhance the porosity of SD soil compared to HM and SC forests.

3.2. Soil Chemical Properties under Different Vegetation Types

The soil pH across the four sample plots was mildly alkaline within the 0–60 cm soil layer, ranging between 7.82 and 8.19. Within this depth, the mean pH values for LS (7.92) and HM (7.94) were significantly lower than those of SD (8.07) and SC (8.04) ($p < 0.05$). Moreover, in the 0–20 cm soil layer, the pH of LS, HM, and SC was significantly lower than that of SD. The pH of SD remained relatively stable ($p > 0.05$) in different layers, while the pH of LS, HM, and SC demonstrated an increasing trend with depth.

The SOM within the 0–60 cm layer varied between 0.67 and 5.98 g/kg, with a decreasing trend with increasing soil layers. The SOM in the 0–20 cm surface layer of the LS, HM, and SC was significantly higher than that in the 40–60 cm, indicating a surface aggregation effect. The mean SOM values over 60 cm in LS (3.18 g/kg), HM (1.87 g/kg), and SC (2.08 g/kg) were significantly higher than that in SD (0.89 g/kg) ($p < 0.05$). The SOM of the vegetation-covered samples was greater than that of SD in all soil layers, and the maximum value was 5.98 g/kg in the 0–20 cm soil layer of LS, which was 4.7, 2.3, and 2.3 times greater than that of SD, HM, and SC, respectively. There was no significant difference in the SOM between HM and SC in the 0–40 cm soil layer ($p > 0.05$). However, in the 40–60 cm layer, the SOM of SC was significantly higher than that of HM ($p < 0.05$).

The changes of TN and TP in the profile were generally consistent with the SOM pattern and aggregated toward the surface. Within the 0–60 cm depth, TN was notably higher in LS, registering at 0.22 g/kg in comparison to that of HM (0.09 g/kg), SC (0.12 g/kg), and SD (0.12 g/kg) ($p < 0.05$). The TN of SC in the 0–20 cm layer was significantly higher than that of HM and SD. As deeper soil depths, the TN of HM and SC did not show a significant difference compared to that of SD ($p > 0.05$). Similarly, TP was substantially greater in LS at 0.31 g/kg than in HM (0.20 g/kg), SC (0.21 g/kg), and SD (0.28 g/kg) ($p < 0.05$). The highest concentrations of TN (0.38 g/kg) and TP (0.22 g/kg) were identified within the 0–20 cm layer of LS.

Across the 0–60 cm layer, the soil total potassium (TK) did not significantly differ among different vegetation types ($p > 0.05$), suggesting that the presence of vegetation cover did not notably influence the TP content of sandy soil. However, the TP of LS, HM, and SC differed significantly between the soil layers and basically decreased with increasing soil layers; the TP in SD did not present significant differences ($p > 0.05$) across the soil layers.

3.3. Comprehensive Evaluation of Soil Quality

The findings presented in Sections 3.1 and 3.2 reveal that the value of each soil indicator differed across various vegetation types; i.e., the capacity of different vegetation types to

affect various soil indicators was not uniform, and the comprehensive soil quality could not be reflected by a single indicator. Consequently, the SQI was utilized in this study to conduct a comprehensive assessment of soil quality under various vegetation types.

A principal component analysis was performed on 11 indicators of different sites, yielding the eigenvalues, variance contribution, common factor variance, and loading matrices of each principal component (Table 2). It was observed that the first two principal components had eigenvalues exceeding 1, specifically, 7.501 and 12.238. Their contribution rates were 68.19% and 11.25%, respectively, with a cumulative contribution rate of 79.44%. This indicated that the majority of the information could be summarized by these two principal components.

Table 2. Principal component analysis of soil index of different vegetation restoration types.

Properties	Component 1	Component 2	Common Factor Variance	Weights
SNW	0.795	0.435	0.853	0.107
BD	0.888	−0.376	0.956	0.081
SMC	0.937	−0.079	0.895	0.100
CMC	0.950	−0.068	0.910	0.102
TPO	0.915	−0.313	0.956	0.087
CPO	0.625	0.539	0.710	0.093
pH	0.686	−0.465	0.727	0.055
SOM	0.877	−0.072	0.794	0.093
TN	0.915	0.060	0.933	0.104
TP	0.885	0.202	0.827	0.107
TK	0.457	0.492	0.974	0.072
Eigenvalue	7.501	1.238		
Variance Contribution	68.187	11.252		

Therefore, the first two principal components were selected for a comprehensive evaluation of soil quality. In the first principal component (PC1), high coefficients were observed for SNW, BD, SMC, CMC, TPO, SOM, TN, and TP. However, a strong correlation was observed among BD, SMC, CMC, TPO, SOM, TN, and TP (Figure 2). Consequently, CMC, which presented the highest coefficients, was chosen as an indicator for the calculation of the SQI in PC1. Since the correlation between soil pH and other indicators was not significant ($p > 0.05$), pH was also selected as an indicator for the computation of the SQI in PC1. In the second principal component (PC2), CPO registered a high coefficient and was consequently chosen as an indicator for the computation of the SQI.

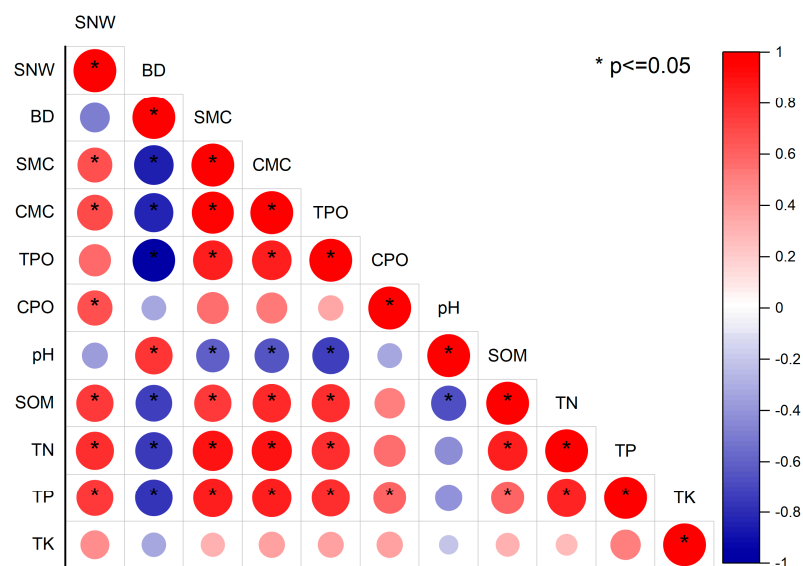


Figure 2. Correlation among different soil properties in the study area.

In summary, soil CMC, pH, and CPO were selected as indicators for calculating the SQI. The results of the SQI for different vegetation types according to Equations (1)–(3) were LS (0.15) > HM (0.11) > SC (0.10) > SD (0.08); i.e., the highest soil quality was found in LS, while the SQI of the HM and SC sites was slightly higher than that of SD, which exhibited the lowest SQI.

4. Discussion

Revegetation of desertified land improves soil physical properties and nutrient status through two main mechanisms. First, root growth and spreading alters soil compactness. Second, the decomposition of dead roots returns most inorganic nutrients back to the soil [30]. Vegetation also reduces wind speed and thus decreases wind erosion of the topsoil [31]. This reduction in erosion also leads to improved soil physicochemical properties. Of course, it should be noted that different vegetation types do not have identical effects on soil properties. In this study, compared to SD, the vegetated plots had greater SNW, SMC, CMC, TPO, CPO, SOM, TN, and TP values, as well as lower BD and pH values. Furthermore, the effect of vegetation on soil properties decreased with increasing soil depth.

Compared to SD, the surface-layer SNW values of LS, HM, and SC were greater, while the deep-layer water content was lower. This is because in arid areas, vegetation cover accumulates litter which effectively delays surface runoff and increases surface layer SNW. Meanwhile, the root distribution of LS, HM, and SC was all within 0–110 cm, primarily concentrated in the 0–40 cm range [32–34]. Other studies have shown that the growth of deep-rooted shrubs or perennial herbaceous plants, which consume relatively more water in the deeper soil layers, resulting in a lower water content in the deeper soil layers [35]. In the SD plots, precipitation could hardly form surface runoff and infiltrated more readily, leading to relatively higher deep-layer moisture [36].

BD is one of the factors characterizing soil fertility. In this study, compared with SD, the 0–20 cm topsoil BD was significantly reduced under all three vegetation types. This is because under the vegetation cover, the gradual decomposition of litter, dead roots, and other residues leads to the gradual accumulation of humus in the soil, making the soil loose and porous, thus reducing BD. As reported in related research, after a restoration period of nine years, the root biomass of HM in 0–40 cm soil depth measured at 122.51 g/m² [34]. The root biomass of SC within 0–40 cm reaches 164.7 g/m² [32]. For LS, a species characterized by a developed rhizome network and robust clonal reproduction capacity [37], its root system can extend to a biomass of 367.7 g/m² in 0–40 cm depth [33]. This phenomenon explains why in this study, the BD of LS in the deeper soil strata remains higher than that of the forest land.

The pH values of LS, HM, and SC were all lower than that of SD. The reason is that the litter accumulated under vegetation cover produces organic acids during decomposition, to some extent increasing the soil acidity. The differences in pH are closely related to the vegetation coverage and root distribution [38]. Soil SOM, TN, TP, TK, and other soil nutrient indicators are important metrics for measuring soil quality and fertility. Higher values of these indicators represent higher soil fertility [39]. The SOM in the soil surface of the study area was generally significantly higher than that of deeper layers, indicating a shallower distribution and topsoil accumulation, which was related to the accumulation and decomposition of litter in the soil surface. The input of organic matter mainly comes from litter [40]. Among the four different sites, compared with HM and LC, LS has higher coverage and more litter accumulation on the surface, so the content of SOM in the surface soil is slightly higher. Organic matter itself has a loose and porous structure, which can effectively promote the formation of soil granular structure and affect soil porosity and water-holding capacity [41]. Our results agree with this view based on the observations that SMC, CMC, TPO, CPO, and BD significantly correlated with SOM ($p < 0.01$; Figure 2).

The SOM and TN values of all the soil samples demonstrated a decreasing trend with the increase in soil depth, exhibiting similar patterns (Table 3, Figure 2). This observation can be attributed to the soil ecosystems of the chosen sites, which closely resemble closed

systems, where the TN is primarily regulated by the accumulation and decomposition of the soil's SOM [42]. The coefficients of variation for the average SOM, TN, TP, and TK content in the 0–60 cm soil layer of the four sites are, respectively, 40.57%, 36.09%, 22.0%, and 2.8%. Compared to SOM and TN, the variations in TP and TK content across different sites are relatively minor. This is because the phosphorus and potassium content in the soil is mainly influenced by the parent material of the soil, its degree of weathering, and the inherent soil properties. Despite the impact of biological factors, their influence is modest [43]. Meanwhile, in such arid regions characterized by sparse rainfall and weak leaching, the potassium released from mineral weathering typically cannot be leached out of the soil, resulting in soils rich in potassium, with content significantly higher than TN and TP. The accumulation and decomposition of surface litter, along with the metabolism of plant roots, have a positive impact on soil nutrients [44], leading to a noticeable accumulation of soil nutrients at each sampling site.

Table 3. Soil chemical properties under different vegetation restoration patterns.

Stand	Layer/cm	SD	LS	HM	SC
pH	0–20	8.07 Ac	7.85 Aa	7.86 Aa	7.96 Ab
	20–40	8.08 Ab	7.82 Aa	7.92 Ba	8.03 Bb
	40–60	8.06 Ab	8.04 Ba	8.02 Ca	8.11 Cc
	0–60	8.07 b	7.92 a	7.94 a	8.04 b
SOM/(g/kg)	0–20	1.27 Aa	5.98 Bc	2.64 Bb	2.62 Bb
	20–40	0.70 Aa	2.09 Ab	2.04 Bb	1.99 Ab
	40–60	0.69 Aa	1.46 Ab	0.94 Aa	1.64 Ab
	0–60	0.89 a	3.18 c	1.87 b	2.08 b
TN/(g/kg)	0–20	0.12 Aa	0.38 Bb	0.09 Aa	0.17 Ca
	20–40	0.14 Aa	0.15 Aa	0.10 Aa	0.11 Ba
	40–60	0.11 Aa	0.15 Aa	0.08 Aa	0.10 Aa
	0–60	0.12 a	0.22 b	0.09 a	0.12 a
TP/(g/kg)	0–20	0.27 Aa	0.43 Bb	0.25 Ba	0.28 Ba
	20–40	0.28 Ab	0.27 Ab	0.19 Aa	0.19 Aa
	40–60	0.29 Ab	0.30 Ab	0.17 Aa	0.13 Aa
	0–60	0.28 b	0.31 b	0.20 a	0.21 a
TK/(g/kg)	0–20	19.13 Aa	18.73 Ba	19.78 Bb	18.65 Ba
	20–40	18.29 Aab	17.53 Aa	16.78 Aa	18.88 Bb
	40–60	18.56 Ab	17.13 Ab	15.20 Aa	16.61 Aa
	0–60	18.66 a	17.79 a	17.26 a	18.05 a

Note: Different lowercase letters indicate significant differences ($p < 0.05$) between different communities in the same soil layer. Different capital letters indicate significant differences ($p < 0.05$) between different soil layers in the same community.

Overall, the soil fertility indicators SOM, TN, TP, etc. were greater in LS than in HM, SC, and SD in this study. Besides the presence of more decaying matter and returned root biomass at the LS sites, the annual turnover rate of the entire root system is faster for grasslands than shrubs and faster for shrubs than trees [45]. This relatively higher root turnover rate for herbaceous plants could be one contributing factor to the superior comprehensive fertility quality of the soil at LS sites [38].

SQI reflects the quality of soil and is important for evaluating sustainable land use and effective management [46]. In this study, 11 soil physicochemical property indicators were selected, and CMC, pH, and CPO were chosen through PCA to evaluate the comprehensive soil quality. According to the evaluation results, the soil fertility quality of LS was better and obviously superior to the other vegetation types. In summary, from the perspective of soil properties, fencing for grassland restoration is a more suitable vegetation restoration measure.

Indeed, vegetation restored on sandy land can protect vegetation from human and livestock disturbance, enhance community biodiversity, and improve soil nutrients. However,

as the succession time extends, the surface biological crust will gradually increase, which might not only compete with plants for nutrients but also affects water infiltration [12]. Consequently, further research is required to determine the optimal enclosure period for this region.

5. Conclusions

- (1) This study unveils a progressive increase in bulk density and pH with the depth of the soil layer, whereas the soil physical properties such as porosity, water-holding capacity, and natural water content, as well as nutrient content, exhibit a decreasing trend.
- (2) The influence of vegetation on soil physicochemical properties is predominantly noticeable within the 0–20 cm soil layer, and this effect varies with the type of vegetation restoration. Compared to *Hedysarum mongolicum* Turcz. (HM) and *Salix cheilophila* Schneid. (SC), *Leymus secalinus* Tzvel. demonstrates the most significant enhancement of comprehensive soil quality.
- (3) These conclusions still require further validation through additional research, particularly within more stages of succession and vegetation types. It is also imperative to gather information regarding root systems to enhance our understanding of the mechanisms by which the types influence soil properties. This would subsequently steer ecological restoration and reconstruction in this region.

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