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Soil Quality Evaluation and Driving Factor Analysis of *Hippophae rhamnoides* Plantations in Coal Mine Reclamation Areas Based on Different Restoration Durations

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Abstract: The driving factors affecting soil quality were identified to evaluate the effect of vegetation on soil quality in coal mine reclamation areas with various restoration durations. This study used *Hippophae rhamnoides subsp.sinensis Rousi* with different reclamation durations (3, 4, 5, 6, and 7 years) in the abandoned land area of the Juxinlong coal mine in Ordos as the research subject. Artificial and abandoned grasslands were selected as the study's controls. A soil quality evaluation model was constructed to assess the soil quality in the reclamation area. A structural equation model was used to thoroughly analyze the driving factors affecting soil quality in the study area. The findings show that: (1) Reclamation duration significantly affected the physicochemical characteristics of the soil. As the reclamation duration increased, soil nutrients such as organic carbon accumulated while the bulk density index (BD) decreased. (2) The soil quality index of *Hippophae rhamnoides* forest land in China was the highest after 6 years of reclamation. The *Hippophae rhamnoides* forest land with the lowest soil quality index after 4 years of reclamation differed significantly from that after 6 years ($p < 0.05$). The soil quality index (SQI) of 6a (years) significantly increased by 67.44% compared to 4a. (3) By constructing a structural equation model, it was found that physical indicators (saturated water content and silt) and reclamation durations were the main drivers of soil quality. SQI had a strong interaction with organic matter (OM) and different restoration durations. The findings of this study will serve as important guidelines for future quantitative evaluation of soil quality following land reclamation and management during the ecological restoration process.

Keywords: soil quality index; *Hippophae rhamnoides* plantation; coal mine reclamation area; structural equation model

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1. Introduction

Open-pit coal mining is the primary source of mineral resources in China, which supports economic development and provides a significant number of basic materials. Resource extraction significantly negatively impacts the ecological environment and land resources and accelerates economic growth [1]. Ecological restoration is more challenging because most open-pit mines are located in ecologically fragile areas in arid and semi-arid regions [2]. Therefore, the most important challenge in the current ecological construction of mining areas is the restoration of mining areas [3]. To achieve sustainable development, land reclamation in coal mining areas is an important step in ecological restoration [4]. Vegetation restoration, water conservation, and soil erosion reduction can prevent the loss of soil nutrients in coal mining subsidence areas [5]. Artificial vegetation reconstruction is one of the primary methods for restoring vegetation and improving soil quality in reclaimed open-pit mine areas [6]. In addition to improving species diversity and promoting soil development and restoration in damaged areas, vegetation restoration and reconstruction can significantly speed up the ecosystem restoration process in mining areas. Plant roots effectively promote the nutrient cycle between plants and soil during the restoration process; however, seasonal litter also has a significant impact on soil fertility changes [7–9], in which in turn affect ecosystem function and soil quality [10].

Ecological restoration depends on soil restoration [11]. Soil quality and vegetation establishment are interdependent components and both contribute to the sustainable function of an ecosystem [12]. Plant growth is carried out by soil, which also serves as the building block for its development. Changes in soil quality directly impact how plants grow and develop, the amount of water, heat, and gas required, and how vegetation grows in succession. Simultaneously, changes in vegetation facilitate the improvement and stabilization of soil structure [13]. Recently, research has focused on using vegetation to improve and enhance the soil quality of degraded land. Several researchers have mainly focused on the effects of different vegetation types on heavy soil metals [14,15], physical soil conditions [16], soil nutrients [17,18], etc., as well as the effects of vegetation reclamation on soil remediation in mining areas and another degraded land areas. According to research, using native shrubs as restoration plants can improve the environmental conditions and initiate vegetation succession in mining areas [19]. *Hippophae rhamnoides* is an excellent economic tree species for vegetation reconstruction and restoration in the North and land reclamation in mining areas because it has the following characteristics: windbreak and sand fixation properties, drought and cold resistance, rapid growth, root sprouting, strong adaptability, nitrogen fixation, and soil cultivation. It is the principal ecological and economical tree species for land reclamation and ecological restoration in mining areas in arid and semi-arid areas [20,21]. The roots of *Hippophae rhamnoides* penetrate the soil deeply and provide food for microorganisms in a large soil volume. In semi-arid areas, it may thus take several years for this plant species to improve soil fertility [22]. The effectiveness of reclamation has been significantly improved by artificial vegetation restoration, and the timing of vegetation planting is a key determinant of that improvement. The improvement of soil quality is more significant the longer the vegetation restoration durations [23]. The contents of soil OM, AN, available phosphorus (AP), and available potassium (AK) will increase as the reclamation duration increases [24].

The status of vegetation restoration is directly correlated with the physiochemical characteristics of the soil. Therefore, land reclamation and ecological restoration can be better understood by comprehending the response mechanisms of soil and vegetation restoration [25]. However, time rather than space methods are used for most research on the vegetation and soil in coal mine reclamation areas. Therefore, the changes in soil quality and its primary driving factors following *Hippophae rhamnoides* forest land reclamation in continuous time series are rarely reported. Therefore, this study uses the research target of the Juxinlong Coal Mine reclamation area in Ordos. A *Hippophae rhamnoides* forest land with a continuous reclamation period of 3a–7a, an artificial grassland of 7a, and an abandoned grassland of 7a were assessed. This study aims to provide a scientific basis and data support for the quantitative evaluation of soil quality and land management in the process of land reclamation and ecological restoration in this area and other coal mine reclamation areas in the future by analyzing the soil quality of *Hippophae rhamnoides* forest land with different reclamation durations and the main factors driving the change in soil quality.

2. Materials and Methods

2.1. Overview of the Study Area

The Juxinlong coal mine is at 110°4′ E, 39°54′ N in the eastern part of Dongsheng District, Ordos, Inner Mongolia Autonomous Region. It is located in the sand-covered loess hilly area on the northeastern margin of the Mu Us Desert, with serious water and wind erosion. It has a temperate continental climate; the summers are hot, and the winters are cold. *Hippophae rhamnoides* plantation was used for the preliminary land restoration of coal mine wasteland due to drought, decreased rain, low soil moisture, and a low nutrient content. The study area includes *Hippophae rhamnoides*, *Hippophae rhamnoides Linn. Cv.*, and *Achnatherum splendens*. Due to recent vegetation restoration, *Hippophae rhamnoides* dominates the vegetation [26] (Figure 1).

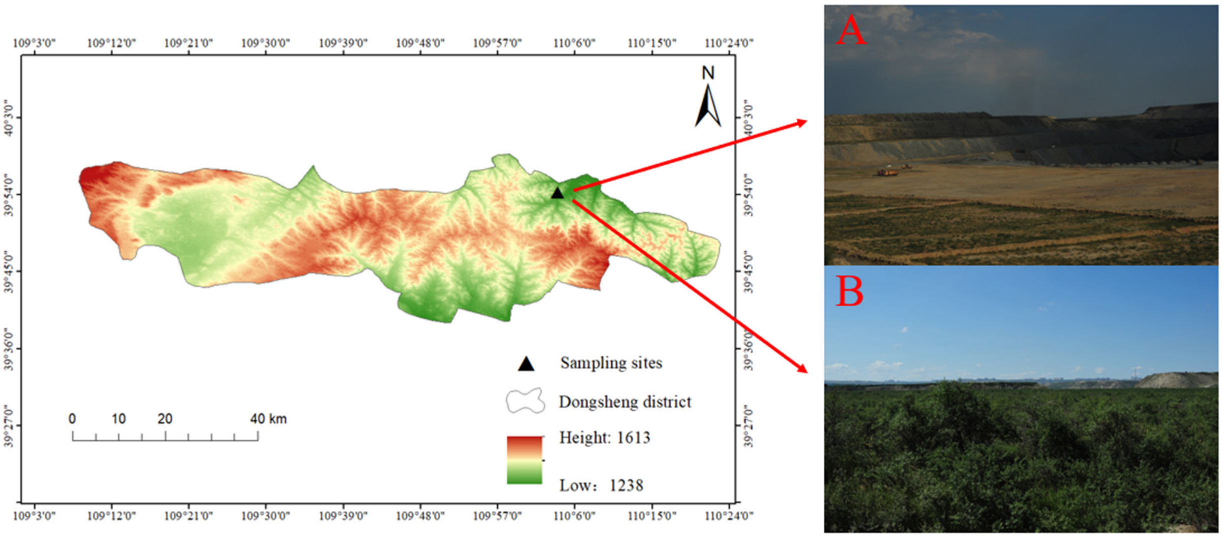

Figure 1. Sample plot map. Note: (**A**) mine site before restoration measures; (**B**) mine site after restoration measures.

2.2. Layout of Sample Plots

The *Hippophae rhamnoides* forest planted in the reclamation area of the study area between 2011 and 2015 was selected by the research group through field research. The reclamation period was 3–7 years. We set up a 20 m × 20 m standard sample plot to allow sampling and investigate the adjacent artificial and abandoned (control) grasslands [26] (Table 1).

Table 1. Basic information of sampled land.

Sample Number	Plot Type	Restore Year (yr)	Altitude (m)	Plant Spacing (m) × Row Spacing (m)	Base Diameter (cm)	Height (cm)
1	*Hippophae rhamnoides*	7	1360	2 m × 2 m	3.0 ± 0.11	157 ± 3.37
2	*Hippophae rhamnoides*	6	1360	2 m × 2 m	3.5 ± 0.11	166 ± 4.64
3	*Hippophae rhamnoides*	5	1370	2 m × 2 m	3.7 ± 0.13	183 ± 4.04
4	*Hippophae rhamnoides*	4	1370	2 m × 2 m	3.2 ± 0.1	172 ± 2.80
5	*Hippophae rhamnoides*	3	1340	2 m × 2 m	3.2 ± 0.13	138 ± 2.62
6	Abandoned land	7	1390	/	/	/
7	Artificial grassland	7	1390	/	/	/

2.3. Sample Collection and Soil Index Determination

Three 1 m deep soil profiles were set up in each standard plot, and soil samples were collected using the ring knife method. The soil samples were divided into five layers starting from the surface: 0–20 cm, 20–40 cm, 40–60 cm, 60–80 cm, and 80–100 cm. Three replicates from each layer of the same profile were collected to determine the physical characteristics of the soil. Simultaneously, the soil samples collected from each profile layer were packaged into self-sealing bags and returned to the laboratory for natural air drying. Physical indicators are measured as follows [27]: The soil water content was measured using the drying method. The soil bulk density (BD) was sampled by a ring knife (100 cm^3). The soil moisture content (SMC), capillary water-holding capacity (CWHC), and total capillary porosity (TCP) were measured using the ring knife immersion method. The soil chemistry indicators refer to soil analysis in agricultural chemistry. The measurement methods for the soil chemical indicators are as follows: The soil particle size was determined using a BT-9300S laser particle size analyzer, the soil pH was determined using a Rex brand pH

(PHS-3C) meter, the soil conductivity was determined using Fangzhou Technology, i.e., a multifunctional conductivity meter (DDS-608), the soil available nitrogen (ALN) was determined using the alkaline hydrolysis diffusion antimony method, available phosphorus (AP) was determined using the sodium bicarbonate method, and available potassium (AK) was determined using the NH_4OAc extraction flame photometer. First, the insoluble silicates in the soil samples were decomposed into soluble compounds using NaOH melting. Finally, a flame photometer was used for the determination. The soil organic matter was determined using the potassium dichromate volumetric method [28]. The carbon in the soil organic matter was first oxidized with an excess of $K_2Cr_2O_7$-H_2SO_4 solution under heated conditions and then calibrated with $FeSO_4$ calibration solution, and finally the organic matter content was calculated. Total phosphorus (TP) was determined using the sodium hydroxide molybdenum antimony colorimetric method.

2.4. Soil Quality Evaluation Methods

2.4.1. Establishment of the Soil Quality Scoring Model

The measured soil index values were converted into acceptable scores between 0 and 1 by a linear evaluation model. The equations selected for this study were "the more the better" and "the less the better". The model is as follows:

$$S_L = \frac{X - L}{H - L} \tag{1}$$

$$S_L = 1 - \frac{X - L}{H - L} \tag{2}$$

where S_L represents the linear score (0–1), X represents the measured value of the index, L represents the lowest value of the index, and H represents the highest value of the index. Equation (1) represents "the more the better" index scoring function, and Equation (2) represents "the less the better" index scoring function [29].

2.4.2. Evaluation Index Weights

The more the contribution of an index to the overall variance, the more it can reflect the common factor variance determined using principal component analysis. Therefore, principal component analysis was used in this study to calculate the weight value of each index. The weight was determined by dividing the common factor variance of each index by the sum of the common factor variance of all indicators [29].

The soil quality index was determined once the score and weight of each index were obtained using Equations (1) and (2):

$$SQI = \sum_{i=1}^{n} W_i S_i \tag{3}$$

S_i represents the index score, n represents the number of indicators, and W_i represents the index weight value. The higher the soil quality index (SQI) value, the better the soil quality.

2.5. Data Analysis

In this study, Excel 2016 was used for data processing and calculation, and the Statistical Package for Social Sciences 24.0 was used to perform correlation analysis of the data. One-way analysis of variance was used to analyze the significant differences between treatments. Origin 2021 was used for drawing, and R 4.2.3 was used to analyze the structural equation model.

3. Results

3.1. Analysis of the Soil Index Characteristics of the Hippophae rhamnoides Forest across Different Reclamation Durations

Table 2 shows that regarding the different soil indexes in the study area, there were significant differences in AK, CWHC, TCP, OM, TP, and C/N ($p < 0.05$). Soil BD, total nitrogen (TN), C/P, and N/P did not differ significantly ($p > 0.05$). The average contents of AK, AP, OM, and TP increased until they reached the maximum in the seventh year of reclamation with the increase in reclamation duration. The average BD decreased as the reclamation duration increased, and the average TP, OM, AK, and AP contents and C/P were significantly higher in the late stage of *Hippophae rhamnoides* restoration compared with the early stage. The coefficient of variation of pH (4.21%), TCP (5.78%), CWHC (9.49%), and other indicators was low, indicating low variation, as per the standard of coefficient of variation [30]. The coefficient of variation of C/P (197.44%), C/N (123.47%), and OM (66.55%) was high, indicating moderate and strong variation. Soil chemical indexes had a higher variance than physical indexes in the study area following vegetation restoration after coal mine reclamation. This is because they were more sensitive to the soil under different reclamation durations. Vegetation restoration significantly affected the soil SOC, TN, and TP contents and the N:P and C:P ratios as the reclamation duration increased. The C:N, C:P, and N:P values showed an upward trend with increased reclamation duration.

3.2. Construction of the Soil Quality Evaluation System Based on the Linear Model

3.2.1. Soil Factor Variance and Weight Analysis of Soil Quality Evaluation

It can be seen from Figure 2 that the highest weight value of all physical and chemical indicators was sand, and the lowest was OM. Sand had the largest contribution rate to the soil quality index of *Hippophae rhamnoides* reclamation under different durations in the study area, followed by silt.

3.2.2. Analysis of the Soil Quality Index

As shown in Figure 3, the soil quality of *Hippophae rhamnoides* forest land with different reclamation durations was as follows: *Hippophae rhamnoides* for 6 years (0.653) > *Hippophae rhamnoides* for 7 years (0.623) > *Hippophae rhamnoides* for 5 years (0.611) > abandoned grassland (0.511) > artificial grassland (0.423) > *Hippophae rhamnoides* forest for 3 years (0.42) > *Hippophae rhamnoides* forest for 4 years (0.39). The soil quality of *Hippophae rhamnoides* forests in China increased significantly and reached the maximum in the sixth year of reclamation with an increase in reclamation duration. Compared to artificial grassland and *Hippophae rhamnoides* forest land, abandoned grassland had a significantly higher soil quality index after 4 years of reclamation.

3.3. Analysis of the Driving Factors of the Soil Quality of Hippophae rhamnoides Forest in Different Years

To describe the relationship between the soil quality and soil physicochemical factors of *Hippophae rhamnoides* forest land with different reclamation durations, a structural equation model (SEM) was constructed (Figure 4). Different reclamation durations, AP, OM, and physical indexes (SMC, silt) were the main influential factors that led to changes in soil quality. In SEM, the path coefficients of SQI with different reclamation durations, AP, OM, and physical indexes were 0.64, −0.17, 0.19, and 0.56, respectively, indicating that the positive change in SQI with different reclamation durations was the most significant. The path coefficient between different recovery durations and AP and OM was >0.8, indicating a strong interaction between different recovery durations and SQI and OM. The interaction of different restoration durations, AP, OM, and physical indicators affected the temporal variation of soil quality.

Table 2. Soil physical and chemical properties.

Indicator	3a	4a	5a	6a	7a	RC	LC	Coefficient of Variation%
pH	8.067 ± 0.117 b	7.67 ± 0.246 cd	7.913 ± 0.006 bc	8.423 ± 0.015 a	8.137 ± 0.176 b	7.527 ± 0.259 d	7.563 ± 0.091 d	4.21%
EC/(mS/cm)	146.847 ± 6.076 a	99.99 ± 16.675 b	127.037 ± 27.563 ab	124.267 ± 8.458 ab	121.637 ± 5.605 ab	123.633 ± 22.546 ab	58.267 ± 8.358 c	24.71%
ALN/(mg/kg)	8.99 ± 0.248 b	9.813 ± 0.484 ab	8.877 ± 0.589 b	11.033 ± 1.559 a	10.777 ± 0.751 a	3.578 ± 0.486 c	3.578 ± 0.819 c	39.40%
Clay/%	2.783 ± 0.389 b	2.99 ± 0.699 ab	3.847 ± 0.474 a	3.747 ± 0.621 a	2.987 ± 0.346 ab	3.333 ± 0.212 ab	3.7 ± 0.221 a	12.87%
Silt/%	58.507 ± 3.396 abc	49.257 ± 7.997 c	58.743 ± 10.455 abc	63.643 ± 6.143 ab	54.993 ± 1.808 bc	66.483 ± 3.343 a	68.44 ± 1.698 a	11.20%
Sand/%	38.707 ± 3.78 abc	47.75 ± 8.268 a	37.403 ± 10.935 abc	32.6 ± 6.768 bc	42.02 ± 2.16 ab	30.18 ± 3.394 bc	27.854 ± 1.523 c	19.05%
AK/(mg/kg)	98.443 ± 32.693 b	86.22 ± 3.563 b	93.67 ± 3 b	169.11 ± 17.011 a	177.223 ± 7.065 a	41.556 ± 3.834 c	42.889 ± 6.466 c	53.52%
AP/(mg/kg)	11.117 ± 5.197 d	16.43 ± 2.015 cd	26.887 ± 5.485 ab	21.08 ± 2.774 abc	29.047 ± 1.797 a	14.768 ± 0.762 cd	19.084 ± 10.461 bcd	32.64%
SMC/(g/kg)	36.937 ± 2.555 b	31.31 ± 2.856 b	37.92 ± 2.764 b	44.323 ± 5.18 a	33.233 ± 1.785 b	37.764 ± 3.5 b	34.951 ± 4.311 b	11.41%
CWHC	29.64 ± 1.207 a	22.87 ± 1.892 c	29.297 ± 0.93 a	29.343 ± 0.673 a	27.027 ± 0.8 ab	25.004 ± 2.954 bc	28.736 ± 2.353 a	9.49%
BD/(g/cm^3)	1.213 ± 0.095 b	1.37 ± 0.082 a	1.183 ± 0.117 b	1.19 ± 0.05 b	1.313 ± 0.055 ab	1.167 ± 0.082 b	1.196 ± 0.072 b	6.25%
TCP	44.883 ± 0.89 ab	39.99 ± 1.751 c	44.693 ± 0.714 ab	47.78 ± 1.984 a	44.29 ± 0.745 b	43.358 ± 1.41 bc	41.433 ± 3.575 bc	5.78%
OM/(g/kg)	1.617 ± 0.23 c	1.697 ± 0.733 c	4.11 ± 0.926 c	4.087 ± 0.74 c	5.55 ± 0.521 bc	9.218 ± 5.066 ab	10.722 ± 3.338 a	66.55%
TN/(g/kg)	0.275 ± 0.092 a	0.215 ± 0.185 a	0.365 ± 0.327 a	0.533 ± 0.334 a	0.495 ± 0.359 a	0.143 ± 0.021 a	0.24 ± 0.121 a	45.24%
TP/(g/kg)	0.46 ± 0.017 bc	0.47 ± 0.036 bc	0.567 ± 0.085 bc	0.583 ± 0.101 ab	0.693 ± 0.05 a	0.444 ± 0.083 c	0.472 ± 0.051 bc	17.32%
C/N	10.781 ± 2.89 c	26.665 ± 26.195 bc	31.821 ± 21.281 bc	25.104 ± 28.433 bc	27.043 ± 16.835 bc	106.678 ± 46.822 a	98.768 ± 78.022 ab	123.47%
C/P	6.083 ± 1.051 b	6.139 ± 2.428 b	12.457 ± 1.682 b	12.335 ± 3.007 b	13.893 ± 2.185 b	38.819 ± 26.094 a	40.097 ± 15.379 a	197.44%
N/P	0.602 ± 0.218 a	0.478 ± 0.447 a	0.605 ± 0.493 a	0.931 ± 0.623 a	0.709 ± 0.508 a	0.335 ± 0.102 a	0.514 ± 0.285 a	49.40%

Note: The single factor variance LSD method was used to analyze the difference between the same index in the same soil layer ($p < 0.05$), and different letters indicate significant differences. Bulk density: BD; Soil moisture content: SMC; Conductivity: EC; Organic matter: OM; Available phosphorus: AP; Total phosphorus: TP; Available potassium: AK; Available nitrogen: ALN. 3a: Reclamation of *Hippophae rhamnoides* for 3 years; 4a: Reclamation of *Hippophae rhamnoides* for 4 years; 5a: Reclamation of *Hippophae rhamnoides* for 5 years; 6a: Reclamation of *Hippophae rhamnoides* for 6 years; 7a: Reclamation of *Hippophae rhamnoides* for 7 years; RC: artificial grassland; LC: abandoned grassland.

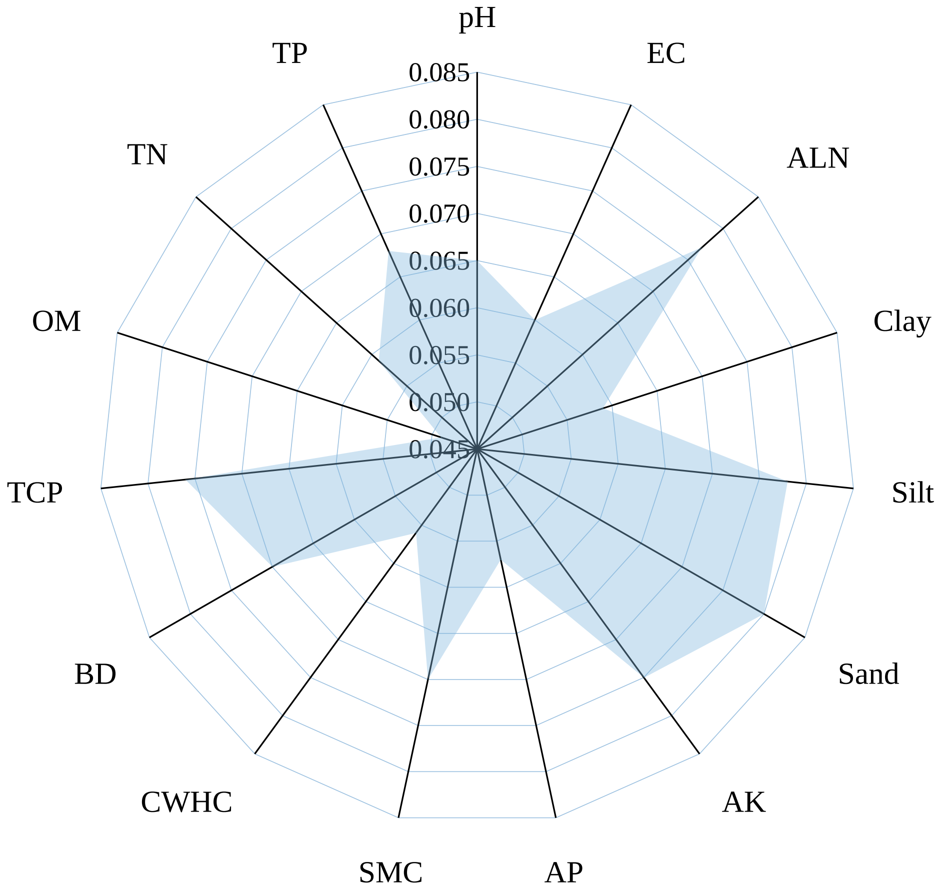

Figure 2. Weight of soil indicators.

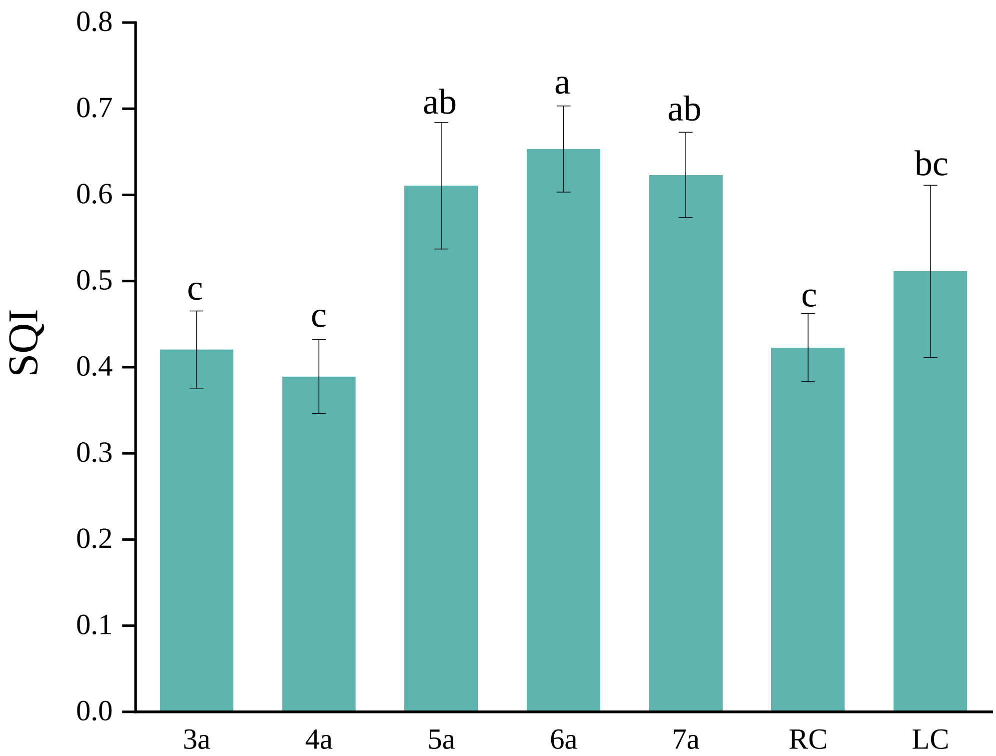

Figure 3. SQI after restoration; different letters indicate significant differences ($p \leq 0.05$).

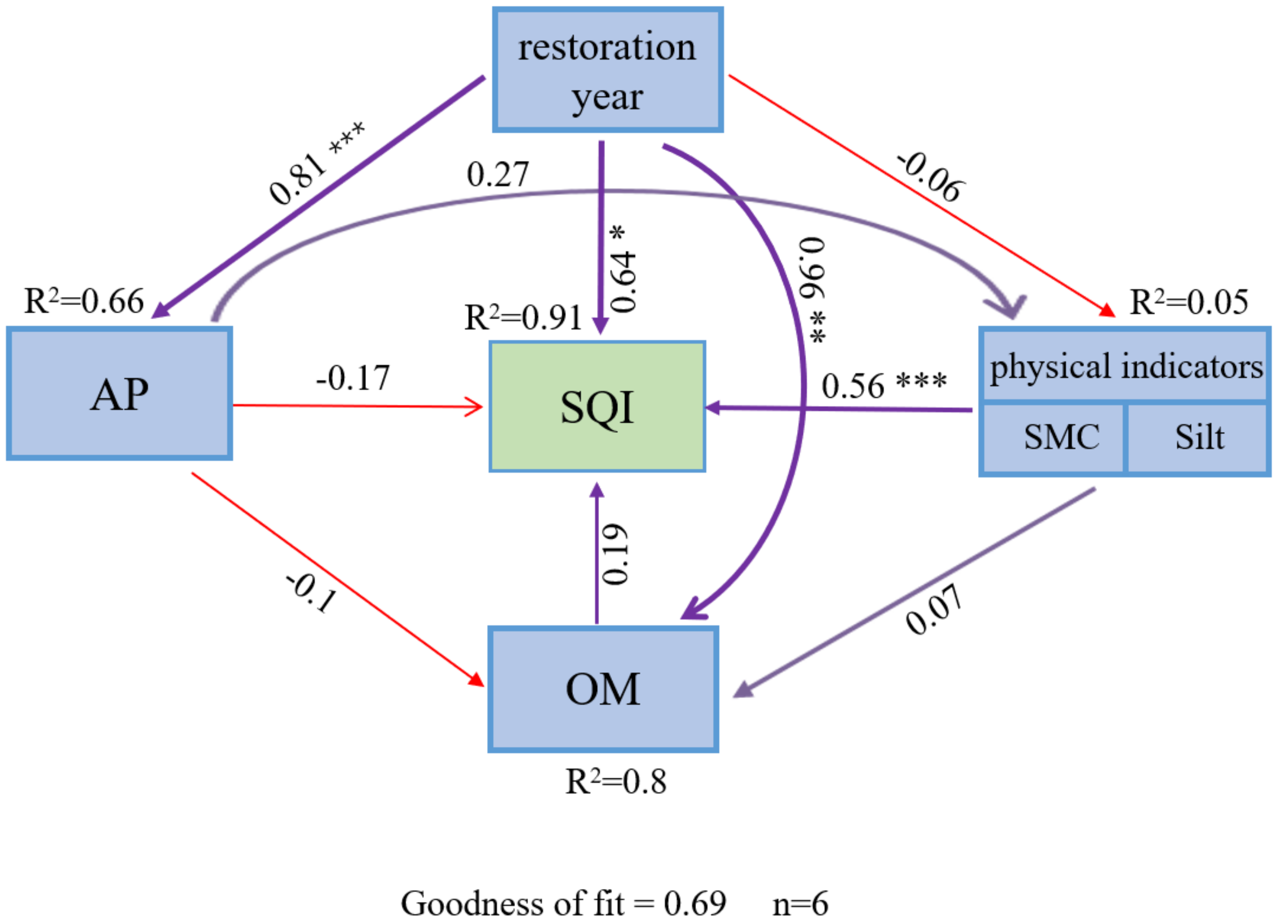

Figure 4. Structural equation model (SEM) analysis of the effects of physical indicators, OM, and restoration duration on the soil quality index (SQI). Red arrows indicate negative effects and purple arrows represent positive effects. Numbers adjacent to arrows are path coefficients (*p*-values) indicating the effect size of the relationship. *** represents a significant correlation at the 0.001 level, ** represents a significant correlation at the 0.01 level, and * represents a significant correlation at the 0.05 level.

4. Discussion

4.1. Difference Analysis of Soil Physicochemical Indexes in Different Reclamation Years

The nutrients and biogeochemical cycles associated with new soils are the main factors limiting soil restoration in mining areas [31]. Among the different soil physical and chemical indicators, BD, SOC, TP, and TN are easily influenced by human activities, especially in the 0–10 cm soil layer [32]. According to studies, TN, alkali-hydrolyzable nitrogen, available phosphorus, and soil organic matter increase with restoration duration [33]. This is consistent with the findings of this study. With increasing reclamation duration, the OM and AP levels in soil increased. Time has an impact on the accumulation of soil nutrients during the process of land reclamation [34]. Studies have shown that carbon, nitrogen, and phosphorus, which are the basic elements of organisms, can reflect how well plants absorb nutrients [35]. A key indicator for evaluating the soil nutrient supply capacity, quality, and function is the stoichiometric ratio of soil nutrients [36]. TN and TP in the soil are the main determinants and indicators of soil fertility and quality and are strongly related to soil productivity. Decreased TN and TP levels will decrease the soil nutrient supply, fertility, porosity, and permeability, reducing soil productivity [37]. The rate of soil OM decomposition is inversely proportional to C:N, a sensitive index of soil quality, and soil with lower N values mineralizes quickly [38]. From Table 2, it can be inferred that the *Hippophae rhamnoides* forest land reclaimed for 6–7 years had a lower C:N ratio than the land that had been reclaimed in the early stage, indicating that the 6–7-year reclamation in the study area was more conducive to the transformation of soil organic matter than the early stage of reclamation. The amount of SOC and TN in the soil varies significantly with the reclamation duration, whereas the amount of TP in the soil barely changes [39]. This difference may be due to the fact that while TP is primarily affected by the parent material of the soil, SOC and TN are more strongly influenced by litter decomposition and plant absorption and utilization [40]. N:P is an important index to determine the limitations of phosphorus and nitrogen as a nutrient index to assess production limitations. In this study, the *Hippophae rhamnoides* woodland lacked phosphorus, and phosphorus limited *Hippophae rhamnoides* growth in different years.

4.2. Soil Quality Analysis of Different Reclamation Durations

The reclamation duration affects the distribution of soil nutrients by changing the ecosystem's composition and plant growth environment. A longer reclamation duration changed the dominant tree species and understory vegetation, disrupting the balance between the soil nutrient supply and vegetation growth, development, and physiological metabolism. Additionally, the physical binding effect of soil on plant roots and the chemical secretion binding effect of root exudates significantly improve soil characteristics [41,42]. Forest growth influences the decomposition of litter to form humus, direct root penetration, soil microbial quantity, and community diversity, altering the hydrothermal conditions in the forest. This successfully improves the physical and chemical properties of the soil [43]. According to Li Pengfei, the soil quality of the mining area significantly increased as the reclamation duration increased, with the soil quality index under shrub planting for 20 years came closest to the soil quality level under the restoration of natural vegetation [29,44,45]. The results of Wang Jijie et al. were corroborated by the comprehensive evaluation of the soil quality of the *Hippophae rhamnoides* plantation, which revealed that the soil quality in the study area showed a trend of 'decrease–increase–decrease' with the change in reclamation duration [46]. The afforestation process causes some disruption to the soil environment and nutrient loss in the early stages of reclamation. After the growth of the vegetation community is stabilized, the soil quality begins to improve significantly. The plant growth rate is fast, and nutrient uptake increases significantly. As a result, the soil nutrient supply is lower than the growth consumption, resulting in a decline in soil quality.

The amount of surface litter increased, and the amount of nutrient regression accumulate through the humification process increased with the reclamation duration, increasing the soil nutrient content. In the study area, land reclaimed by Chinese thorn forest for 7 years had a lower soil quality index than land reclaimed by *Hippophae rhamnoides* for 6 years. *Hippophae rhamnoides* will decline after 5–6 years of growth [47]. Although the *Hippophae rhamnoides* forest has declined, it has helped to foster the renewal of undergrowth vegetation. According to the survey, it was found that *Hippophae rhamnoides* regeneration seedlings and plant species were significantly higher in the plots reclaimed for 7 years than in other woodlands. This may have resulted in a significant consumption of soil nutrients and an uncoordinated relationship between soil and vegetation growth, which has been associated with a decline in soil quality. Aboveground biomass and species diversity also increased with the reclamation duration. Aboveground biomass was closely correlated with soil characteristics [46]. The fact that abandoned grassland in the study had better soil quality than artificial grassland may be related to the unreasonable plant configuration of artificial grassland, excessive density, and species, which caused the vegetation to absorb many nutrients from the soil to maintain high biomass. The vegetation of artificial grassland grew rapidly, while aboveground biomass continued to accumulate. The cumulative rate was higher than the rate at which soil nutrients were returned. Therefore, improving the management of *Hippophae rhamnoides* woodland in the reclamation area is crucial to maintain soil productivity and create good environmental ecology.

4.3. The Dominant Factor Analysis of Soil Quality Change

C, N, and P abundance and deficiency in soil impact the nutritional balance of the system, which might indicate the status of plants at different growth stages and their adaptability to the environment [47]. This is consistent with the results of this study. The interaction between different recovery durations and SQI and OM is the most critical (Figure 4). This may be because *Hippophae rhamnoides* is a deciduous shrub that grows rapidly. In the forest, the branches and leaves grow densely. Every year, there will be a lot of understory litter. The shallow layer is where the root system is mainly dense. Inorganic acids, amino acids, and phenols are secreted into the soil through plant litter and roots during the humification process, which can decompose nutrient elements like insoluble P and K in the parent soil material and increase the content of available components [42,48,49]. However, the restored vegetation in the mining area is still in the primary stages of succession. More plants lacking phosphorus are growing as the reclamation duration increases and the soil quality index increases [50]. SMC and silt (physical indicators) significantly impact soil quality. Silt is a significant component of the mechanical composition of the soil. The gradation and content of its grain size components directly affect the soil's physical and chemical properties [51]. The mechanical components of the soil *Hippophae rhamnoides* plantation increased with the *Hippophae rhamnoides* reclamation duration; the sand content decreased while soil clay and silt increased. This shows that the *Hippophae rhamnoides* plantation has a positive impact on improving the mechanical composition of the soil in the mining area. This is similar to the research results of Li Yuqiang and Guo Yujia [52,53]. According to the findings of this study, different restoration durations had an indirect impact on soil OM, which had an impact on soil quality. The richness of the understory herbaceous or vegetation diversity increases with reclamation duration, resulting in a continuous accumulation of understory litter, which increases soil organic matter and the soil quality index.

5. Conclusions

The findings of this study showed that the OM and TP contents increased with the increase in reclamation duration, but the BD decreased with the increase in reclamation duration. The SQI was calculated using 15 soil physicochemical characteristics. The artificial vegetation restoration significantly improved the soil quality of the mining area. The following was the soil quality index ranking: *Hippophae rhamnoides* for 6 years > *Hippophae rhamnoides* for 7 years > *Hippophae rhamnoides* for 5 years > abandoned grassland > artificial grassland > *Hippophae rhamnoides* forest for 3 years > *Hippophae rhamnoides* forest for 4 years. In the 6 years of reclamation, the soil quality index of the *Hippophae rhamnoides* forest land was the highest. The structural equation model showed that the soil quality of the *Hippophae rhamnoides* woodland was directly affected by the reclamation duration and indirectly affected the soil quality by changing different physicochemical characteristics. Therefore, it is suggested that in the future, suitable technical means and measures can be proposed for the recovery period to carry out precise construction and management while carrying out land remediation and management in the coal mine reclamation area and forest tending in the study area.

Author Contributions: N.A. designed the study; F.Q., G.L., C.L. and F.Q. assisted in the experimental design; F.Q., N.A. and Q.R. performed the experimental preparation, performed fieldwork, and entered data; Q.R. analyzed field data; Q.R. wrote and edited the manuscript. All authors have read and agreed to the published version of the manuscript.

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