SOIL PROPERTIES IN DIFFERENT YEARS OF CULTIVATION ABANDONMENT IN THE MIDSTREAM AND DOWNSTREAM OF SHIYANG RIVER AREA

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Abstract. To understand changes of soil properties in different years of cultivation abandonment in the midstream and downstream of Shiyang River area, soil physicochemical characteristics, microbial population, soil microbial biomass, relationships between them and comprehensive evaluation of soil fertility quality were analyzed. The results showed that soil pH increased slightly, soil water content, sand content, the number of bacteria, the number of actinomycetes and SMBN (soil microbial biomass nitrogen) decreased then increased, soil organic carbon, total potassium, Quick-available K, Quick-available P, SMBC (soil microbial biomass carbon), SMBP (soil microbial biomass phosphorus) and SMBC/SMBN increased then decreased, total nitrogen increased then decreased and tended to be stable, total phosphorus and the number of fungi decreased then increased and decreased finally, and different abandoned years had different significant difference. From the correlation analysis and principal component analysis (PCA), there were close correlations among the soil physical characteristics, soil chemical characteristics and the number of soil microbes, soil microbial biomass. The key factors determining the soil quality were the soil pH, sand content, soil water content, soil water content, total nitrogen, Quick-available K, the number of fungi, SMBC and SMBN. The results that the effects of 4a on the soil during restoration were better for soil improvement than the other abandoned years, making the abandoned years of 4a more critical for use in the ecological restoration and control of the midstream and downstream of Shiyang River area.

Keywords: *soil microbial characteristics, soil physicochemical characteristics, soil fertility, midstream and downstream of Shiyang river, years of abandoned cultivated lands*

Introduction

Shiyang River is a typical inland river in the arid regions of northwestern China. Its downstream Minqin area was once a natural oasis with plenty water and rush grass (Feng, 1963). However, in recent decades, with the continuous expansion of the population and economic scale of midstream area of Shiyang River, especially the expansion of artificial oases, the downstream surface water resources are decreasing day by day, the groundwater is seriously over-exploited, the degree of mineralization is rising, natural vegetation is subject to serious disturbance and damage, a series of ecological problems such as desertification and salinization have been intensified (Zhang et al., 2016; Chang et al., 2016), causing large-scale land to be abandoned and uncultivated which deteriorates into secondary grassland. If these secondary grasslands

are not properly protected, degradation will speed up, wind erosion and desertification will occur with emergence of new source of sand and dust, forming a vicious circle and seriously damaging soil ecosystem of the secondary grassland in the middle and lower reaches of Shiyang River (Chai et al., 2015). Therefore, how to properly protect and restore secondary grassland in abandoned oasis area in the middle and lower reaches of Shiyang River is an ecological problem that needs to be settled urgently.

Soil serves as the carrier of many ecological processes in ecosystems and the substrate for plant growth (Hu and Guo, 2012). Its physicochemical properties and biological properties are key indicators reflecting restoration degree of soil ecosystems (Yuan et al., 2012). Studies have shown that soil microbes in soil ecosystems mainly participate in material circulation and energy flow by decomposing animal and plant residues, which serve as supply source and reservoir pool of soil nutrients, affecting vegetation succession and soil quality (Kardol et al., 2007). The amount of soil microbes is used to study and evaluate soil microbial regulation functions, which can reflect the effects of various soil factors on soil microbes and its effects on plant growth and soil fertility, and exert certain regulation on the whole ecosystem (Harris, 2003). Soil microbial biomass constitutes living soil organic matter, which is a sign of soil activity and one of the early warning indicators of soil ecosystem changes (Singh et al., 2014). At present, research on the evolution of soil properties mainly focuses on physicochemical properties of soil (Zhao et al., 2012), while there are few reports on the evolution of soil properties in the Shiyang River Basin. In view of this, this paper studies change characteristics of physical properties, chemical properties and microbial properties of secondary grassland with different abandoned years in different middle and lower reaches of Shiyang River, discusses the relationship between them and makes comprehensive evaluation of soil quality in this area, with a view to making in-depth exploration into evolution process of soil properties in Shiyang River Basin, and providing a theoretical basis for ecological restoration and management in the area.

Materials and methods

Overview of the study area

The test site was selected in Huanghui Village and Ziyun Village, Xiqu Town, north of Minqin County, Gansu Province. The geographical coordinates are located at east longitude 103°07'50"~103°37'56" and north latitude 39°01'30"-39°03'28". The altitude is 1297~1306 m, the annual average temperature is 7.4°C, the average annual precipitation is 110 mm which is mainly concentrated in July~ September, the annual average evaporation is 2644 mm, the annual sunshine hours are 2832.1 h, and the annual average wind speed is 2.3 m/s. The soil type is gray brown desert soil. The main shrub plants in the plot include *Nitraria schoberi*, *Kalidium foliatum*, *Lycium chinense*, *Nitraria sibirica*, *Reaumuria songarica*, etc. The herbaceous plants include *Convolvulus arvensis*, *Chenopodium album*, *Halogeton arachnoideus*, *Suaeda glauca*, *Peganum harmala*, *Salsola ikonnikovii*, etc. (Chai et al., 2015).

Sample site setting and soil sample collection

In September 2012, interview and investigation was conducted in the forestry department and local residents of Minqin County to accurately grasp abandoned time in the middle and lower reaches of Shiyang River. By using method of space replacement

time, sections with uniform plant growth, small changes in microtopography, and without topography change owing to natural factors or soil material redistribution caused by human factors were selected as test area. While ensuring that soil parent materials of the sample site was consistent, 9 wastelands where crops have been planted 1, 2, 3, 4, 5, 8, and 15. 24 and 31a with an area of 1 hm² was selected as sample site (see Table 1).

Table 1. Basic condition of sample sites

Abandoned years(a)	Altitude (m)	Longitude/ Latitude	Dominant plants species	Accompanying species	(Plant type before abandonment)
1a	1304	E103°36'03 N39°03'28"	Chenopodium album, Convolvulus arvensis, Echinopilon divaricatum, Peganum harmala	<i>P. nigellastrum</i> , <i>Chloris virgata</i> , <i>Corispermum hyssopifolium</i> , <i>Polygonum aviculare</i> et al	The autumn crops
2a	1303	E103°36'09" N39°03'25"	<i>Sonchus oleraceus</i> , <i>P. nigellastrum</i> , Halogeton arachnoideus, <i>Lepidium lotifolium</i>	<i>Atriplex sibirica</i> , <i>Chenopodium album</i> , <i>Chloris virgata</i> , <i>Euphorbia pekinensis</i> et al.	The autumn crops
3a	1297	E103°36'09" N39°02'36"	<i>P. nigellastrum</i> , Halogeton arachnoideus, <i>Lepidium lotifolium</i> , <i>Acroptilon repens</i>	<i>Limonium mau-reum</i> , <i>Phragmites australis</i> , <i>Peganum harmala</i> , <i>Eragrostis pilosa</i> et al.	The autumn crops
4a	1305	E103°36'13" N39°02'34"	<i>Peganum harmala</i> , <i>Acroptilon repens</i> , <i>P. nigellastrum</i> , <i>Suaeda glauca</i>	<i>Phragmites australis</i> , <i>Chloris virgata</i> , Halogeton arachnoideus et al.	The autumn crops
5	1304	E103°35'58" N39°02'9"	<i>Lycium ruthenicum</i> , Halogeton arachnoideus, <i>Lepidium lotifolium</i> , <i>Peganum harmala</i>	<i>Cardaria draba</i> , <i>Clematis florida</i> , <i>P. nigellastrum</i> , <i>Chloris virgata</i> et al.	The autumn crops
8a	1304	E103°07'54" N39°02'54"	<i>Lycium ruthenicum</i> , Halogeton arachnoideus, <i>Peganum harmala</i> , <i>P. nigellastrum</i>	<i>Phragmites australis</i> , <i>Acroptilon repens</i> , <i>Limonium mau-reum</i> , <i>Achnatherum splendens</i> et al.	The autumn crops
15a	1304	E103°37'02" N39°01'45"	<i>Lycium ruthenicum</i> , Halogeton arachnoideus, <i>P. nigellastrum</i> , <i>Limonium mau-reum</i>	<i>Atriplex sibirica</i> , <i>Salsola ikonnikovii</i> , <i>Lepidium lotifolium</i> , <i>Echinopilon divaricatum</i> et al.	The autumn crops
24a	1306	E103°36'24" N39°02'34"	<i>Lycium ruthenicum</i> , <i>Kalidium foliatum</i> , <i>Reaumuria songarica</i> , <i>Phragmites australis</i>	Halogeton arachnoideus, <i>Nitraria schoberi</i> , <i>P. nigellastrum</i> , <i>Eragrostis pilosa</i> et al.	The autumn crops
31a	1306	E103°36'13" N39°02'34"	<i>Lycium ruthenicum</i> , <i>Kalidium foliatum</i> , <i>Reaumuria songarica</i> , <i>P. nigellastrum</i>	<i>Nitraria schoberi</i> , <i>Scorzonera hispanica</i> , Halogeton arachnoideus, <i>Peganum harmala</i> et al.	The autumn crops

Five soil sample collection points were selected in each site using “S” method, and each collection point was repeated three times. 0~10 cm soil samples were taken with soil drill (soil drills type: SoilMoisture0200.0206L06.0215F1L05). After the same soil samples were uniformly mixed, the soil samples were separated into two parts by quartering and enclosed to be brought back to the laboratory. One part is used for the determination of soil physicochemical properties, and the other part is used for the determination of soil biological properties (at 4°C for less than 24 h).

Determination method

Determination of soil physicochemical properties

Soil pH was determined by pH instrument (PHS-3S), soil moisture content was measured by oven drying method in incubator (Shanghai yiheng DHG-9030A electric thermostat), and the sand content (the sum of coarse sand and fine sand) was measured by Malvern Mastersizer 2000. The organic carbon was determined by potassium dichromate-sulfuric acid external heating method, total nitrogen was determined by Kjeldahl distillation method, total phosphorus, available phosphorus were determined by NaHCO₃ extraction- Mo-Sb-Vc colorimetric method, total potassium, available

potassium were determined by atomic absorption spectrophotometry. Refer to "Soil Agricultural Chemistry Analysis" for the specific methods (Bao, 2005).

Determination of soil microbial properties

(1) The amount of soil bacteria, fungi and actinomycetes was determined by flat surface smearing (Xu and Zheng, 1986), in which beef extract peptone medium was used for bacteria, Martin-Bengal red medium was used for fungus, and modified Gaoshi No.1 medium was used for actinomycete.

(2) Determination of soil microbial biomass

Soil microbial biomass was determined by chloroform fumigation incubation method (Sparling et al., 1997; Yao and Huang, 2006).

1) Soil microbial biomass carbon (SMBC): was determined by K₂Cr₂O₇-H₂SO₄ external heating method. The calculation formula is:

$$\text{SMBC (mg/kg)} = (\text{Ec} - \text{Ec}_0) / k_{\text{Ec}} \quad (\text{Eq.1})$$

2) Soil microbial biomass nitrogen (SMBN): was determined by Kjeldahl determination method. The calculation formula is:

$$\text{SMBN (mg/kg)} = (\text{En} - \text{En}_0) / k_{\text{En}} \quad (\text{Eq.2})$$

3) Soil microbial biomass phosphorus (SMBP): was determined by molybdenum blue colorimetric method. The calculation formula is:

$$\text{SMBP (mg/kg)} = (\text{Ep} - \text{Ep}_0) / k_{\text{Ep}} \quad (\text{Eq.3})$$

In the formula: Ec, En and Ep are the contents of organic carbon, total nitrogen and phosphorus in the fumigated soil extract, Ec₀, En₀ and Ep₀ are the contents of organic carbon, total nitrogen and phosphorus in the unfumigation soil extract, and k_{Ec}, k_{En} and k_{Ep} are correction coefficients which are 0.38, 0.54 and 0.40, respectively.

Data Analysis and Processing

The test data was the average of 3 replications, and analysis of variance, correlation analysis, and principal components analysis (PCA) were performed using SPSS 19.0 software and tabulated with Excel 2010.

Results and analysis

Characteristics of physic-chemical properties of soil

The soil physicochemical properties of secondary grassland with different abandoned years are shown in *Table 2*. With the extension of abandoned years, soil pH generally shows an upward trend with a range of 8.0-8.5; the soil water content decreases first in 1-4a, 8- 24a and then increases in 4-8a, 24-31a, with significant difference between different years ($P < 0.05$), of which the maximum is reached at 8a (7.26%); the sand content in the soil decreases first in 1-4a, 5- 8a, 15-24a and then increases in 4-5a, 8-15a, 24-31a, with significant difference between different years ($P < 0.05$).

With the extension of abandoned years, soil organic carbon increases first in 1-2a, 3-4a, 5-15a, 24-31a and then decreases in 2-3a, 4-5a, 15-24a, with maximum of 1.76%

achieved at 4a; the total nitrogen increases first in 1-2a and 3-4a, then decreases (2-3a) and finally stabilizes (4-31a), with the maximum of 0.07 achieved at 1a, 4a; the total phosphorus decreases first in 1-3a, 4-5a, 8-15a, 24-31a and then increases in 3-4a, 5-8a, 15-24a, with significant difference between different abandoned years ($P < 0.05$), and the maximum of 0.66 g/kg is achieved at 1a, followed by 4a (0.58 g/kg); the total potassium increases first in 1-2a, 4-5a, 15-24a and then decreases in 2-4a, 5-15a, 24-31a, with the maximum of 38.17g/kg achieved at 5a. The available potassium increases first in 1-3a, 4a-15a, 24-31a and then decreases in 3-4a, 15-24a, with the maximum of 636.09 mg/kg achieved at 15a, showing significant difference between different years ($P < 0.05$); the available phosphorus decreases first in 1-2a, 3-5a, 15-24a and then increases in 2-3a, 5-15a, 24-31a, with the maximum of 0.178 mg/kg achieved at 3a, showing no significant difference between different abandoned years ($P > 0.05$).

Soil microbial properties

As can be seen from *Table 3*, the number of soil bacteria decreases sharply (1-2a) with the extension of abandoned years, increasing first after 2a (2-4a, 8-24a) and then decreasing (4-8a, 24-31a); the number of fungi decreases first (1-2a, 4-5a, 8-31a) and then increases (2-4a, 5-8a); the number of actinomycetes decreases first (1-3a, 4-5a, 8-15a, 24-31a) and then increases (3-4a, 5-8a, 15-24a), reaching the maximum of 8.37×10^5 cfu/g at 8a and showing significant difference between different abandoned years ($P < 0.05$); soil microbes have different compositions, and with the extension of abandoned years, the proportion of bacteria, fungi and actinomycetes decreases to a different extent, of which bacteria accounts for the largest proportion, with the maximum of 95.65% achieved at 1a, while the proportion of fungi is less than 1%.

With the extension of abandoned years, SMBC fluctuates, increasing first (1-2a, 3-8a, 15-24a) and then decreasing (2-3a, 8-15a, 24-31a), showing significant difference between different abandoned years ($P < 0.05$), with the maximum of 979.13 mg/kg achieved at 8a; SMBN decreases first (1-2a, 4-8a, 15-24a) and then increases (2-4a, 8-15a, 24-31a); SMBP increases first (1-2a, 3-4a) and then decreases (2-3a, 4-31a), reaching the maximum of 168.35 mg/kg at 4a; SMBC/SMBN increases first (1-2a, 3-8a, 15-24a) and then decreases (2-3a, 8-15a, 24-31a), reaching the maximum of 9.2 at 8a.

Correlation between soil microbial properties and soil physic-chemical properties

From *Table 4*, it can be known that the number of soil bacteria is significantly positively correlated with total phosphorus ($P < 0.01$), and significantly negatively correlated with pH, total potassium and available potassium ($P < 0.01$). The number of fungi is significantly positively correlated with organic carbon and total nitrogen ($P < 0.01$), significantly negatively correlated with available potassium ($P < 0.01$), and negatively correlated with water content ($P < 0.05$). The number of actinomycetes is significantly negatively correlated with sand ($P < 0.01$), and positively correlated with organic carbon ($P < 0.05$); SMBC is significantly positively correlated with pH ($P < 0.01$), positively correlated with available potassium ($P < 0.05$), and negatively correlated with sand and available phosphorus ($P < 0.05$). SMBN is significantly positively correlated with organic carbon ($P < 0.01$), significantly negatively correlated with water content and available potassium ($P < 0.01$), and positively correlated with total nitrogen ($P < 0.05$). SMBP is significantly positively correlated with organic carbon ($P < 0.01$), and positively correlated with total nitrogen ($P < 0.05$). The correlation between the remaining is not obvious.

Table 2. Soil physic-chemical properties under different abandoned years

Index	Abandoned years (a)								
	1	2	3	4	5	8	15	24	31
pH	8±0.06f	8.09±0.04ef	8.18±0.05de	8.24±0.04cd	8.27±0.02bcd	8.32±0.01bc	8.38±0.04ab	8.45±0.04a	8.5±0.02a
Water content	5.85±0.121b	5.66±0.123b	2.89±0.156d	1.32±0.038e	2.92±0.048ad	7.26±0.047a	3.90±0.286c	1.63±0.020e	3.27±0.239d
Sand content/%	60.15±0.19c	55.51±0.13de	54.87±0.08ef	54.54±0.12ef	65.63±0.15a	54.11±0.55f	62.45±0.02b	53.67±0.92f	56.38±0.07d
Organic carbon/%	1.02±0.009c	1.1±0.012b	0.95±0.46c	1.76±0.046a	0.73±0.011e	0.99±0.008c	1.12±0.013b	0.75±0.013e	0.87±0.015d
Total nitrogen/%	0.05±0.008b	0.07±0.004a	0.03±0.003c	0.07±0.006a	0.03±0.002c	0.03±0.002c	0.03±0.002c	0.03±0.003c	0.03±0.002c
Total phosphorus(g/kg)	0.66±0.002a	0.57±0.004b	0.54±0.008d	0.58±0.006b	0.45±0.003f	0.57±0.006b	0.38±0.005g	0.55±0.001c	0.51±0.005e
Total potassium(g/kg)	34.57±0.05e	37.18±0.40b	36.54±0.25bc	35.60±0.19cd	38.17±0.19a	36.23±0.24bc	34.99±0.48de	37.02±0.49b	36.60±0.28bc
Quick-available K(mg/kg)	266.26±17.07d	357.54±5.75c	383.56±2.94c	277.86±9.29d	380.22±54.61c	479.97±6.46b	636.09±11.43a	520.63±13.83b	529.94±1.33b
Quick-available P (mg/kg)	0.177±0.053a	0.159±0.035ab	0.178±0.12a	0.115±0.064cd	0.106±0.30d	0.132±0.05bcd	0.150±0.001abc	0.106±0.18d	0.134±0.092bcd

The different lowercase letters in the same line indicate different years abandoned cultivated lands have significant different at 0.05 level, the same below

Table 3. The number of soil microbe under different abandoned years

Index	Abandoned years (a)								
	1	2	3	4	5	8	15	24	31
Bacteria/ ($\times 10^5$ cfu/g)	23.06±0.299a	2.22±0.173c	2.68±0.067c	7.30±0.232b	1.11±0.067de	0.45±0.063e	1.37±0.113d	7.71±0.616b	0.45±0.063e
Fungi/ ($\times 10^3$ cfu/g)	0.72±0.063de	0.52±0.067ef	2.16±0.113b	4.65±0.110a	0.72±0.067de	1.10±0.067c	0.91±0.067cd	0.45±0.063f	0.45±0.063f
Actinomycetes/ ($\times 10^5$ cfu/g)	1.04±0.063de	0.46±0.067f	0.46±0.067f	7.69±0.282b	0.59±0.000ef	8.37±0.299a	1.43±0.063d	3.63±0.234c	0.97±0.110def
Percentage of bacteria/%	95.65±0.002a	82.9±0.01b	84.92±0.02b	48.56±0.004d	65±0.01c	5.13±0.006f	48.57±0.03d	67.89±0.01c	31.84±0.04e
Percentage of fungi/%	0.03±0.0002e	0.19±0.0002d	0.69±0.0005a	0.31±0.0001c	0.42±0.0002b	0.12±0.00003d	0.32±0.0002c	0.04±0.00003e	0.32±0.0004c
Percentage of actinomycetes/%	4.32±0.002f	16.9±0.01e	14.39±0.02e	51.13±0.003c	34.58±0.01d	94.75±0.006a	51.1±0.03c	32.07±0.01d	67.84±0.04b
SMBC (mg/kg)	437.40±8.245de	523.13±13.08c	257.91±13.542f	417.86±5.158e	469.75±5.065d	979.13±13.536a	433.27±8.842e	959.48±13.154a	773.17±13.105b
SMBN (mg/kg)	154.45±1.352c	108.98±0.954e	169.59±1.484b	215.50±1.885a	153.84±1.346c	106.42±0.930e	122.65±1.073d	121.64±1.063d	124.32±1.089d
SMBP (mg/kg)	105.89±0.813f	125.88±0.813d	122.64±0.813e	168.35±0.814a	148.14±0.814b	133.65±0.815c	126.73±0.814d	102.81±0.814g	92.92±0.813h
SMBC/SMBN	2.83±0.08f	4.8±0.12d	1.52±0.08h	1.94±0.02g	3.05±0.03f	9.2±0.16a	3.53±0.08e	7.89±0.13b	6.22±0.12c

Table 4. Correlation analysis between soil microbial properties and Soil physic-chemical properties

Index	Bacteria	Fungi	Actinomycetes	SMBC	SMBN	SMBP
pH	-0.536**	-0.145	0.188	0.541**	-0.274	-0.204
Water content	0.104	-0.435*	0.045	0.2	-0.572**	-0.182
Sand content	0.048	-0.031	-0.491**	-0.407*	0.021	0.139
Organic carbon	0.124	0.816**	0.475*	-0.372	0.573**	0.620**
Total nitrogen	0.345	0.531**	0.256	-0.320	0.430*	0.438*
Total phosphorus	0.666**	0.181	0.288	0.133	0.190	-0.125
Total potassium	-0.535**	-0.241	-0.185	0.198	-0.189	0.076
Quick-available K	-0.538**	-0.443**	-0.057	0.442*	-0.609**	-0.372
Available P	0.275	-0.097	-0.380	-0.435*	-0.056	-0.283

** : indicate very significant correlation ($P < 0.01$); * : indicate significant correlation ($P < 0.05$)

Comprehensive evaluation of soil fertility quality

Soil quality assessment can provide a theoretical basis for the restoration and management of degraded land (Kirkegaard et al., 2000). In this study, principal component analysis was used to comprehensively evaluate soil quality (Table 5). The cumulative contribution rate of the first 5 principal components is 87.61%, which is in line with the requirements of principal component analysis. Therefore, the 5 principal component analysis can represent the variation information of soil quality of secondary lands with different abandoned years in the lower reaches of Shiyang River.

Table 5. The loading factor, eigenvalue and contribution ratio of 5 PCAs

Index	The first principal component	The second principal component	The third principal component	The forth principal component	The fifth principal component
pH	-0.634	0.614	0.179	0.184	-0.270
Water content	-0.100	-0.630	0.329	0.168	0.621
Sand content	-0.199	-0.117	-0.770	0.011	0.150
Organic carbon	0.812	0.291	0.098	0.340	0.152
Total nitrogen	0.824	-0.079	0.171	-0.138	0.224
Total phosphorus	0.558	-0.458	0.586	-0.293	-0.171
Total potassium	-0.381	0.293	-0.139	-0.757	0.241
Quick-available K	-0.810	0.252	0.052	0.469	-0.014
Available P	0.164	-0.692	-0.166	0.375	0.091
Bacteria	0.480	-0.596	0.091	-0.031	-0.473
Fungi	0.802	0.530	-0.005	0.155	-0.076
Actinomycetes	0.332	0.506	0.682	0.147	0.147
Soil microbial C	-0.537	0.145	0.785	-0.139	-0.022
Soil microbial N	0.783	0.325	-0.330	-0.055	-0.340
Soil microbial P	0.582	0.574	-0.212	-0.041	0.458
Eigenvalue	5.154	3.065	2.408	1.287	1.227
Rate of variance %	34.361	20.433	16.051	8.578	8.179
Cumulative rate %	34.361	54.794	70.845	79.423	87.603

The first principal component mainly reflects pH, organic matter, total nitrogen, available potassium, fungi and soil microbial biomass nitrogen index (absolute value of load value > 0.6), indicating that it is the most important impact factor in soil quality assessment. The second principal component mainly reflects pH, water content and

bacteria. The third principal component mainly reflects sand content, actinomycetes and soil microbial biomass carbon. The fourth principal component mainly reflects total potassium, and the fifth principal component mainly reflects water content.

From weighting of the eigenvectors and the normalized data, the scores of the 5 common factors in different abandoned years are obtained, and then comprehensive scores of soil fertility quality under different abandoned years are obtained by weighting of scores of the factors and the variance contribution rate (soil quality comprehensive evaluation index). See *Table 6* for the result, which is sorted as abandoned year 4a (1.087) > abandoned year 8a (0.333) > abandoned year 2a (0.007) > abandoned year 3a (-0.087) > abandoned year 15a (-0.157) > abandoned year 1a (-0.183) > abandoned year 24a (-0.253) > abandoned year 31a (-0.363) > abandoned year 5a (-0.383), indicating that abandoned year 4a is a key period of restoration. After abandoned year 5a, soil quality decreased to varying degrees. It can be seen that the sorting results of soil quality comprehensive evaluation index are consistent with the previous demonstration results, so the results of principal component analysis can better reflect the actual conditions of the soil.

Table 6. General sores and ranking under different managements

Abandoned years(a)	Factor score					General sores	Ranking
	Factor1	Factor2	Factor3	Factor4	Factor5		
1	0.917	-2.150	-0.009	0.100	-0.806	-0.183	6
2	0.244	-0.811	0.166	-0.694	1.488	0.007	3
3	0.347	-0.227	-0.801	0.041	-0.417	-0.087	4
4	2.136	1.584	0.243	0.211	-0.310	1.087	1
5	-0.494	0.591	-1.594	-1.489	0.604	-0.383	9
8	-0.389	0.171	1.771	0.351	1.424	0.333	2
15	-0.748	0.289	-1.041	2.118	0.313	-0.157	5
24	-0.916	0.425	1.009	-0.782	-1.471	-0.253	7
31	-1.097	0.128	0.257	0.144	-0.825	-0.363	8

Discussion

The experimental study found that with the extension of abandoned years, soil pH of the secondary grassland with different abandoned years in the lower reaches of Shiyang River gradually increased but did not show significant difference, which was generally alkaline. Soil available potassium content increased in fluctuations, which may be because soil leaching effect increased the available potassium content in the soil surface (Wang, 2016); the soil water content was generally "V"-shaped, and the maximum value appeared at abandoned year 8a, which may be due to the decline of vegetation coverage and surface exposure with the return of farmland to forest (Wang, 2016). In addition, because of the combined effect of precipitation and natural sedimentation, the soil structure is continuously restored, and the soil capillary water is effectively stored (Wang, 2016). Moreover, as abandoned year 8a vegetation is mainly perennial shrubs, such plants can obtain water in deeper soil layers, while surface soil water content contributes little to it (Walter, 1979); soil sand content decreased gradually during abandoned years 1-4a, fluctuated after 5a, and gradually increased after abandoned year 24a. Soil organic carbon, total nitrogen, total phosphorus, total potassium and available phosphorus decreased with the extension of abandoned years. The reason for this change may be that the vegetation richness index and diversity index decreased in

varying degrees with the extension of abandoned years, and then the bare soil area increased gradually. In addition, the lower reaches of Shiyang River has strong wind (Chang et al., 2007), desertification and wind erosion of the sample site thus deteriorate, while soil sand is not easily eroded by wind, causing a large loss of nutrients. Due to the limitation of water and heat, the slow decomposition rate of organic matter reduces the ability of nutrient return (Liu et al., 2016). At the same time, with the extension of abandoned years, vegetation coverage and biomass decrease, which reduces the supplement of soil nutrients by plant residue (Li et al., 2010).

Bacteria in the soil constitute the main microbial group, its maximum number is up to 23.06×10^5 cfu/g, accounting for 95.65% followed by actinomycetes and fungi was the least. This may be because the soil in this study area is slightly alkaline, which is beneficial to the growth of bacteria and actinomycetes, while fungus grows poorly in a slightly alkaline environment. This is consistent with the results of Tan Qiuji (Tan et al., 2014). The number of soil bacteria, fungi and actinomycetes in different abandoned years reaches the highest at abandoned year 1a, abandoned year 4a and abandoned year 8a. During abandoned years 1-8a, field husbandry, fertilization and other agricultural management measures just stopped or stopped for a short time, so the good soil moisture conditions and ventilation, coupled with higher soil nutrient content enabled strong microbial activity. In addition, an increase in the number of soil microbes leads to a corresponding increase in the proportion. With the extension of abandoned years, the trend of soil microbial biomass changed slightly. SMBC content was the highest at abandoned year 8a, SMBN and SMBP contents were the highest at abandoned year 4a, which was significantly higher than that at other abandoned years ($P < 0.05$). This may be because vegetation grew fast at abandoned years 4a and 8a, root biomass and root exudates then increased, so that soil nutrients accumulated continuously. It was also related to the fact that the collected sample was surface soil (0~10 cm). The surface layer accumulated a large number of plant residues which enriched soil organic matter, and also the layer had good hydrothermal and ventilation condition (Wen et al., 2010), providing a suitable environment for microbial growth and reproduction, and promoting biological activity of microbes. The soil microbial biomass carbon and nitrogen ratio are important indicators to characterize whether soil microbial growth is restricted by carbon or nitrogen, which affect the community structure of soil microbes (Yang et al., 2014). Soil $SMBC/SMBN \geq 30$ and $SMBC/SMBN \leq 20$ indicate that soil microbial growth is respectively limited by nitrogen source and carbon source. When $SMBC/SMBN = 25$, it is most beneficial to soil microbial growth, which is conducive to the normal function of soil microbes in ecosystem (Zhang et al., 2012). $SMBC/SMBN$ ranged from 1.5~9.2 in the secondary grassland with different abandoned years in the lower reaches of Shiyang River, indicating that supply quantity of carbon source is the main limiting factor for soil microbial growth. The correlation results also show that soil microbial biomass is related to soil nutrients in different degrees (Niu et al., 2011), which is significantly correlated with soil organic matter, so this conclusion is further confirmed. However, soil represents a relatively complex ecosystem, and soil microbial biomass is also affected by factors such as temperature, air temperature, soil bulk density, etc. which demands comprehensive considerations.

Soil microbes are reservoirs of soil nutrients and play an important role in soil organic matter and nutrient conversion and cycling (Singh et al., 2014). Wang et al. (2010) and Yang et al. (2014) have found that there is a certain correlation between soil microbes and soil physicochemical properties. This study also shows that soil microbial

quantity, soil microbial biomass under different abandoned years are closely related to soil physicochemical properties, good physical environment (moisture, pH and gas permeability) will promote the growth of soil bacteria, fungi and actinomycetes, thereby increasing the number of microbes, and the change in soil microbial quantity will accelerate the soil nutrient cycle, leading to an increase in soil nutrients (Taylor et al., 2002). The principal component analysis showed that indicators such as soil pH, sand, water content, organic matter, total nitrogen, available potassium, fungi, soil microbial biomass carbon, soil microbial biomass nitrogen have a large contribution rate in each principal component, which can be used to evaluate important factors in soil fertility quality of the area. The results of comprehensive evaluation of soil fertility indicated that abandoned year 4a > abandoned year 8a > abandoned year 2a > abandoned year 3a > abandoned year 15a > abandoned year 1a > abandoned year 24a > abandoned year 31a > abandoned year 5a, of which abandoned year 4a is a key period of recovery. This conclusion is consistent with the conclusions obtained from single factor analysis to a certain extent and the two are mutually confirmed.

Conclusion

With the extension of abandoned years, soil pH gradually increased, soil water content, sand content, bacteria number, actinomycetes number, SMBN decreased first and then increased; soil organic carbon, total potassium, available potassium, available phosphorus, SMBC, SMBP, The SMBC/SMBN increased first and then decreased; the total nitrogen first increased, then decreased, then increased and finally stabilized; the total phosphorus and fungi decreased first, then increased and finally decreased. There is a close correlation between soil physicochemical properties and soil microbial quantity and soil microbial biomass. Indicators such as soil pH, sand, water content, organic matter, total nitrogen, available potassium, fungi, soil microbial biomass carbon and soil microbial biomass nitrogen are important factors for evaluating soil fertility quality in this area. It can be inferred from the comprehensive evaluation of soil fertility quality that the abandoned year 4a is the key stage of restoration and control process in Shiyang River Basin management.

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REFERENCES

- [1] Bao, S. D. (2005): Agrochemistry soil analysis Handbook. – Beijing: China Agricultural Press: 23-107.
- [2] Chai, X. H., Wang, L. D., Yao, T. (2015): Effects of different years of cultivation abandonment on soil physical, chemical and microbial characteristics in the midstream and downstream of Shiyang river area. – *Acta Prataculturae Sinica* 24(8): 24-34.
- [3] Chang, Z. F., Zhao, M., Liu, H. J. (2007): Study on dynamic degenerate ecological characteristic of desertification in Minqin. – *Chinese Agricultural Science Bulletin* 23(11): 333-338.

- [4] Chang, G. Y., Wang, L., Zhang, W. X. (2016): Perceptions of peasants in Minqin County for the water conservation policies of Shiyang river basin and their effects. – *Journal of Arid Land Resources and Environment* 30(2): 13-19.
- [5] Feng, S. W. (1963): The evolution of drainage system of the Minqin oasis. – *Journal of Geographical Science* 29(3): 241-249.
- [6] Harris, J. A. (2003): Measurements of the soil microbial community for estimating the success of restoration. – *European Journal of Soil Science* 54(4): 801-808.
- [7] Hu, C. J., Guo, L. (2012): Advances in research of ecological effects of vegetation restoration. – *Ecology and Environmental Sciences* 21(9): 1640-1646.
- [8] Kardol, P., Cornips, N. J., Van Kempen, M. M. L., Bakx-Schotman, J. M. T., van der Putten, W. H. (2007): Microbe-mediated plant-soil feedback causes historical contingency effects in plant community assembly. – *Ecological Monographs* 77(2): 147-162.
- [9] Kirkegaard, J. A., Sarwar, M., Wong, P. T. W., Mead, A., Howe, G. N., Newell, M. (2000): Field studies on the biofumigation of take-all by Brassica break crops. – *Crop and Pasture Science* 51(4): 445-456.
- [10] Li, Z. Y., Li, C. L., Wang, D. Z. (2010): Characteristics of vegetation succession on salinized abandoned fields in lower reaches in Shiyang river. – *Acta Botanica Boreali-Occidentalia Sinica* 30(10): 2087-2092.
- [11] Liu, X. T., Wei, Y. C., Yang, X. L., Hao, M. D., Wei, X. R. (2016): Effects of different re-vegetation patterns on soil organic carbon and total nitrogen in the wind-water erosion crisscross region. – *Chinese Journal of Applied Ecology* 27(1): 91-98.
- [12] Niu, S. Q., Yang, T. T., Li, J. F., Da, W. Y., Yang, J. W. (2011): Seasonal trends of microbial functional groups in Saline-alkali soil and their relationship with soil physicochemical factors in the east Hexi corridor. – *Arid Zone Research* 28(2): 328-334.
- [13] Singh, A. K., Bordoloi, L. J., Kumar, M., Hazarika, S., Parmar, B. (2014): Land use impact on soil quality in eastern Himalayan region of India. – *Environmental Monitoring and Assessment* 186(4): 2013-2024.
- [14] Sparling, G. P., Pankhurst, C., Doube, B. M. (1997): Soil microbial biomass, activity and nutrient cycling as indicators of soil health. – *Biological Indicators of Soil Health*: 97-119.
- [15] Tan, Q. J., Song, T. Q., Peng, W. X., Zeng, F., Du, H. M., Zhang, H., Fan, F. (2014): Characteristics of soil microbial populations and biomass under different ecosystems in a canyon karst region. – *Acta Ecologica Sinica* 34(12): 3302-3310.
- [16] Taylor, J. P., Wilson, B., Mills, M. S., Burns, R. G. (2002): Comparison of numbers and enzymatic activities in surface soils and subsoils using various techniques. – *Soil Biology and Biochemistry* 34: 387-401.
- [17] Walter, H. (1979): *Vegetation of the earth: second edition Handbook*. – NewYork: Springer-Verlag.
- [18] Wang, C. T., Long, R. J., Wang, G. X. (2010): Relationship between plant communities, characters, soil physical and chemical properties, and soil microbiology in alpine meadows. – *Acta Prataculturae Sinica* 19(6): 25-34.
- [19] Wang, L. D. (2016): *Evolution of vegetation and soil system on secondary grassland of abandoned land area in Minqin*. – Lanzhou: Gansu agricultural university.
- [20] Wen, D. R. Y., Li, G., Zhang, J. N. (2010): The study of soil microbial biomass and soil enzyme activity on different grassland in Hulunbeier, Inner Mongolia. – *Acta Prataculturae Sinica* 19(5): 94-102.
- [21] Xu, G. H., Zheng, H. Y. (1986): *Soil Microbial Analysis Method of Manual Handbook*. – Beijing: Agricultural Press: 102-109.
- [22] Yang, N., Zou, D. S., Yang, M. Y., Lin, Z. G., Song, G. T., Chen, Z. Y., Zhao, L. F. (2014): Changes of soil properties in re-vegetation stages on sloping-land with purple soils in hengyang of Hunan Province, South-central China. – *Acta Ecologica Sinica* 34(10): 2693-2701.
- [23] Yao, H. Y., Huang, C. Y. (2006): *Soil Microbial Ecology and Experimental Techniques Handbook*. – Beijing: Science Press.

- [24] Yuan, J. Y., Ouyang, Z. Y., Zheng, H., Xu, W. H. (2012): Effects of different grassland restoration approaches on soil properties in the southeastern Horqin sandy land, northern China. – *Applied Soil Ecology* (61): 34-39.
- [25] Zhang, L. Q., Peng, W. X., Song, T. Q., Zou, D. S., Zeng, F. P., Song, M., Yu, Z., Liu, Y. (2012): Spatial heterogeneity of soil microbial biomass carbon, nitrogen and phosphorus in sloping farmland in a karst region on the Yunnan-Guizhou Plateau. – *Acta Ecologica Sinica* 32(7): 2056-2065.
- [26] Zhang, Y. H., Liu, S. Z., Ji, Y. F. (2016): Spatial distribution pattern and spatial association of *phragmites australis* in the middle reaches of Shiyang river. – *Journal of Desert Research* 36(2): 342-348.
- [27] Zhao, H. L., Zhou, R. L., Zhao, X. Y. (2012): Desertification mechanisms and process of soil chemical and physical properties in Hulunbeir sandy grassland, Inner Mongolia. – *Acta Prataculturae Sinica* 21(2): 1-7.