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Surface-soil Physicochemical Properties in Near Industrial Areas in the Yanchi Desert Steppe

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Abstract: With rapid industrialization, insoluble pollutants are released into the environment due to production, combustion, and transportation. The release of insoluble pollutants can lead to the rapid deterioration of soil quality. Desert steppe ecosystems are unique and are an important resource for ecological conservation in China. The desert grasslands near the Gaoshawo industrial park, Yanchi county, China was used as the sampling area. The study area is located in a different direction from the industrial park, 1–2 km apart, and randomly distributed. The five-point cross-sampling method was used to sample the surface soil (0–20 cm). The method included the collection of five soil samples from each plot, which were mixed. A total of 76 surface soil samples (0–20 cm) representing diferent pollution sources were collected. The total N, total P, organic matter, available P, available K, ammoniacal nitrogen, nitrate-nitrogen, and pH of the samples were analyzed in the lab. The Pearson's co-efficient was used to determine the weightage of the soil quality index. A membership function model was established and the status of soil quality in the study area was calculated by using the soil-quality formula. On this basis, the geostatistics method in ArcGIS 10.2 was used to make the spatial distribution map. The soil indicators and analysis methods of the data collection are helpful to understand the soil quality of the desert grasslands near industrial areas and provide a reference for ecological conservation efforts of the desert grasslands. The dataset includes geographic location data of sample points and content data of soil physical and chemical indicators. The dataset is archived in .xls format, and the data size is 63 KB (compressed into 1 file of 16.64 KB).

Keywords: desert steppe; soil quality; physical and chemical properties; spatial interpolation

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Dataset Availability Statement:

The dataset supporting this paper was published and is accessible through the *Digital Journal of Global Change Data Repository* at: https://doi.org/10.3974/geodb.2021.06.09.V1 or https://cstr.escience.org.cn/CSTR:20146.11.2021.06.09.V1.

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1 Introduction

Soil quality can be defined as the ability of soil to sustain plant and animal productivity, maintain or enhance water and air quality, and support human health and habitats in natural and managed ecosystems[1,2]. Soil quality affects the diversity, functionality, and health of ecosystems[3–5]. The soil quality not only depends on natural factors, but also by but also, anthropogenic factors, such as industrial and agricultural activities[6]. In recent decades, urbanization and industrialization in China have occurred at unprecedented rates[7]. Heavy metal elements are heavily released during production, transportation, and combustion. Large-scale and high-intensity coal mining activities have further threatened the fragile ecosystems in northwest China. Ningxia, in the eastern part of northwestern China, has an arid climate. The grassland types in this area are mainly desert grasslands and steppes, which are distributed in the southern and eastern regions of Ningxia. Coal, oil, and natural gas resources are located in the area. Industrial activities, centered on the development and processing of these natural resources, have greatly promoted local economic development but have negatively impacted the environment. The fragile ecosystems in this region make it susceptible to grassland degradation by improper resource utilization. Therefore, heavy metal pollution has become an important factor to consider, when evaluating the desert steppe soil quality.

The study area is located west of the Gaoshawo town, Yanchi county, Ningxia (106°49′6.18″E, 38°07′9.93″N) and is connected with the Mu Us Desert in the Etuokeqian Banner of Inner Mongolia autonomous region in northern China. It covers an area of 80.46 km^2, at an altitude of 1,409 m, and has a moderate temperate continental climate, with cold winters, hot summers, and an average annual temperature and precipitation of 22.4 °C and 276 mm, respectively. The region is mainly composed of gentle slopes and hills and contains a large amount of oil, coal, natural gas, and other resources. The soil types are mainly calcareous and aeolian sandy soils, with loose particle structure and low concentrations of organic matter and nutrients. The major vegetation types in the area include *Stipa breviflora*, *Agropyron cristatum*, *Pennisetum centrasiaticum*, *Lespedeza potaninii*, *Potentilla chinensis*, and *Artemisia scoparia* Waldst. et Kit. The study area, which is the main area for industrial production and raw material transportation, is crossed by the Qingyin Expressway, 307 National Road, and the Taiyin Railway. In this study, the measured dataset of surface soil quality, of desert steppe under industrial activities, analyzed the measured soil quality indicators of the desert grassland[8]. The results of this study may serve as a reference for the sustainable development of industries in desert steppes.

2 Metadata of the Dataset

The metadata of the Soil dataset of desert steppe surface infected by industrial activities in Yanchi[8] is summarized in Table 1. It includes the dataset full name, short name, authors, year of the dataset, spatial resolution, data format, data size, data files, data publisher, and data sharing policy, etc.

3 Methods

3.1 Sample Collection

In June 2019, a field survey based on a guide for grassland resources and the comprehensive analysis of the slope, soil types, topographic features, landscape features, and accessibility of the industrial park were conducted. At different directions and distances from the industrial park, an interval of 1–2 km was used. A five-point cross-sampling method was used to analyze the surface soil (0–20 cm), wherein five soil samples from each plot were

Table 1 Metadata summary of the Soil dataset of desert steppe surface infected by industrial activities in Yanchi

Items	Description
Dataset full name	Soil dataset of desert steppe surface infected by industrial activities in Yanchi
Dataset short name	SoilDesertSteppeYanchi
Authors	Xu, Z. AAS-2907-2021, Ningxia University, 496409847@qq.com Mi, W. B. AAS-2933-2021, Ningxia University, miwbao@ nxu.edu.cn Mi, N. AAS-2920-2021, Ningxia University, 705484905@qq.com
Geographical region	106º47′17.16″E–107º0′33.59″E, 38º03′12.46″–38º 9′24.95″
Year	June 2019
Data format	.xls
Data size	63 KB (compressed to one single file with 16.64 KB)
Data files	Measured data of desert steppe soil quality in the study area: measured content of latitude and longitude, total N, total P, organic matter, available P, available K, ammoniacal nitrogen, nitrate nitrogen, and pH at 76 sampling points
Foundation	Key R&D Project of Ningxia Autonomous Region (2018BEB04007)
Data publisher	Global Change Research Data Publishing & Repository, http://www.geodoi.ac.cn
Address	No. 11A, Datun Road, Chaoyang District, Beijing 100101, China
Data sharing policy	***Data*** from the Global Change Research Data Publishing & Repository includes metadata, datasets (in the *Digital Journal of Global Change Data Repository*), and publications (in the *Journal of Global Change Data & Discovery*). ***Data*** sharing policy includes: (1) ***Data*** are openly available and can be free downloaded via the Internet; (2) End users are encouraged to use ***Data*** subject to citation; (3) Users, who are by definition also value-added service providers, are welcome to redistribute ***Data*** subject to written permission from the GCdataPR Editorial Office and the issuance of a ***Data*** redistribution license; and (4) If ***Data*** are used to compile new datasets, the 'ten per cent principal' should be followed such that ***Data*** records utilized should not surpass 10% of the new dataset contents, while sources should be clearly noted in suitable places in the new dataset[9]
Communication and searchable system	DOI, CSTR, Crossref, DCI, CSCD, CNKI, SciEngine, WDS/ISC, GEOSS

mixed. The original weight of the sample was greater than 1 kg, and a total of 76 soil samples were collected (Figure 1). During field sampling, appropriate adjustments were made according to the actual environment around 27 preset sampling points. The latitude and longitude of each sample point were recorded using GPS during the sampling, and further environmental information around the sample point was recorded. After the soil was air-dried, roots, rocks, and other debris were removed, and the samples were passed through a 1-mm nylon sieve and bagged for later use. The determination of heavy metals requires a 100-mesh nylon sieve, and the soil was passed through 0.149, 0.25, and 0.5 mm aperture sieves for the determination of the physicochemical properties of the soil. Three groups of parallel experiments were conducted, and the average value was taken. Samples were analyzed according to methods described in a previous study by Bao[10]. The Kjeldahl method was used to determine the total N (TN) content. Near-infrared spectroscopy was used to determine the total P (TP) content. Sodium bicarbonate extraction with molybdenum-antimony resistance colorimetry and flame photometry were used to determine the available P (AP) and available K (AK), respectively. The potassium dichromate method to determine the soil organic matter (SOM). Nitrate nitrogen (NO_3-N) adopts ultraviolet spectrophotometry, ammoniacal nitrogen (NH_4-N) adopts Nessler's reagent colorimetric method and the electric potential method was used to measure the pH value (the water:soil ratio was 5:1).

3.2 Data Collection and Processing

The correlation coefficient and membership function were used to determine the weight and membership degree of the evaluation indexes, while avoiding subjective influences. First, the correlation coefficient between the single index was calculated (Table 2). According to the correlation coefficients, the mean value of the correlation coefficient between a single index and the other indexes was obtained, and the ratio of the mean value to the sum of all indexes was used as the weight of this factor (Table 3).

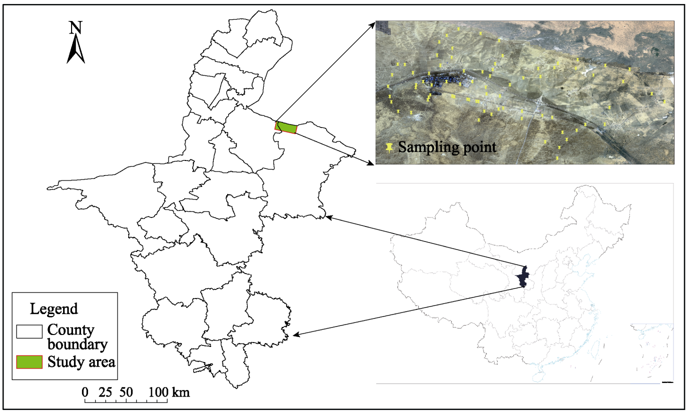

Figure 1 Distribution of soil sampling points in the study area near the Gaoshawo town, Yanchi county, Ningxia, China

Table 2 Correlation coefficients between soil fertility indicators

Fertility index	TN	TP	AP	AK	SOM	NH_4-N	NO_3-N	pH
TN	1							
TP	0.446	1						
AP	–0.364	–0.231	1					
AK	0.373	0.207	–0.113	1				
SOM	–0.122	–0.099	0.0003	–0.222	1			
NH_4-N	–0.069	0.104	–0.014	–0.147	0.044	1		
NO_3-N	0.368	0.123	–0.115	0.171	–0.008	–0.07	1	
pH	–0.075	–0.17	0.212	0.214	0.08	0.017	–0.114	1

Table 3 Fertility index correlation coefficients and their index weights

Fertility index	Mean correlation coefficient	Weights	Fertility index	Mean correlation coefficient	Weights
TN	0.259	0.212	SOM	0.082	0.067
TP	0.197	0.161	NH_4-N	0.066	0.054
AP	0.149	0.122	NO_3-N	0.138	0.113
AK	0.206	0.168	pH	0.126	0.103

Based on the actual situation in the study area, the soil TN, TP, AP, AK, SOM, NH_4-N, and NO_3-N belong to the membership function of Equation 1:

$$f(x)=\begin{cases}1.0 & x\geqslant x_2\\ 0.9(x-x_1)/(x_2-x_1)+0.1 & x_1<x<x_2\\ 0.1 & x\leqslant x_1\end{cases} \quad (1)$$

In combination with the practices in the study area, the minimum and maximum values of each indicator were taken as inflection points x_1 and x_2 of the function. The inflection points of TN, TP, AP, AK, SOM, NH_4-N, and NO_3-N membership are shown in Table 4. The membership value of the pH is shown in Table 5.

The soil quality indicators (SQI) calculation equation was as follows:

$$SQI=\sum_{i=1}^{n}W_i\cdot N_i \quad (2)$$

where W_i is the weight value of the i index, N_i is the membership degree of the ith index, and n is the number of evaluation indexes.

Table 4 Value of the inflection point (x) of the evaluation index in the membership function curve

Inflection point	TN (g/kg)	TP (g/kg)	AP (mg/kg)	AK (mg/kg)	SOM (g/kg)	NH_4-N (mg/kg)	NO_3-N (mg/kg)
x_1	0.07	0.11	5.4	23	1.38	6.38	2.97
x_2	0.91	0.49	17.4	155	45.51	38.11	11.27

Table 5 Memberships values of the pH values

pH	Membership	pH	Membership	pH	Membership
<6.50	0.5	7.51–8.00	0.7	8.26–8.50	0.2
6.50–7.00	1	8.01–8.25	0.5	>8.51	0.1
7.01–7.50	0.9				

4 Data Results and Validation

4.1 Descriptive Statistics of Soil Quality Index

The average pH was 8.13 ± 0.25, i.e., the soil was alkaline (Table 6). The average of TN, TP, and SOM were 0.44 ± 0.19, 0.19 ± 0.06, and 11.08 ± 6.57 g/kg, respectively, and the average of AP, AK, NH_4-N, and NO_3-N were 8.4 ± 3.04, 56.85 ± 25.31, 18.13 ± 6.76, and 5.62 ± 1.76 mg/kg, respectively. The coefficient of variation of the soil pH was 0.03 and showed weak spatial variation. The coefficient of variation for other quality indicators was between 0.31 and 0.59, which is a medium variation. The order of the coefficient of variation were SOM > AK > TN > NH_4-N > AP > TP >NO_3-N > pH. The soil-quality index in the study area was at a poor middle-to-low level, and the overall content of TN, TP, and AP was low.

Table 6 Descriptive statistical characteristics of the soil quality indicators

Fertility index	Max	Min	Mean	Standard deviation	CV
TN (g/kg)	0.91	0.07	0.44	0.19	0.43
TP (g/kg)	0.49	0.11	0.19	0.06	0.32
AP (mg/kg)	17.4	5.4	8.4	3.04	0.36
AK (mg/kg)	155	23	56.85	25.31	0.45
SOM (g/kg)	45.51	1.38	11.08	6.57	0.59
NH_4-N (mg/kg)	38.11	6.38	18.13	6.76	0.37
NO_3-N (mg/kg)	11.27	2.97	5.62	1.76	0.31
pH	9	7.43	8.13	0.25	0.03

4.2 Spatial Submap of Soil Index

According to the spatial distribution map of the measured data for each indicator, the distribution characteristics of TN (Figure 2), TP (Figure 3), and AK (Figure 5) in the study area were similar, with high values concentrated on both sides of the highway. The content of the soil quality indicators was lower in the southwest of the industrial park. AP (Figure 4) and SOM (Figure 6) were high in the southwest and low in the northeast. High NO_3-N (Figure 8) were found to the south of the highway. Some indicators showed a trend of high concentration in the south and low concentration in the north, with the highway as the demarcation point. High-concentration pollutants were mainly distributed in the area north of the study area, and the area south of the industrial park is relatively safe[11]. The pollutants, such as heavy metals, reduced the nutrient content of some samples. However, the spatial distribution of NH_4-N (Figure 9) followed an opposite trend compared to the other indicators. High concentrations of NH_4-N were detected in the north of the highway, which may be related to the soil pH content. The pH content of the soil samples obtained from the south of the highways was higher (Figure 7). As sulfur oxides are emitted by thermal power plants, the smelting of non-ferrous metals, and the production of the coal, the surrounding soil is acidified, resulting in differences in the spatial distribution soil pH. As NH_4-N is easily solubilized in soil and volatilized in alkaline soil, it affects the content of NH_4-N in the soil. The soil-quality index in the study area ranged from 0.383 to 0.404, and the overall soil quality in the majority of the study area was relatively low (Figure 10).

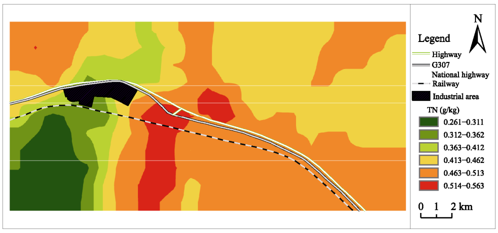

Figure 2 Spatial distribution of soil total N content

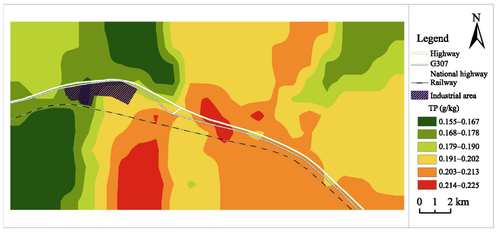

Figure 3 Spatial distribution of soil total P content

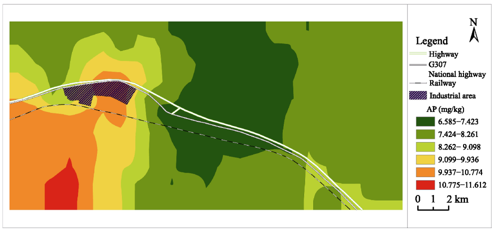

Figure 4 Spatial distribution of soil available P content

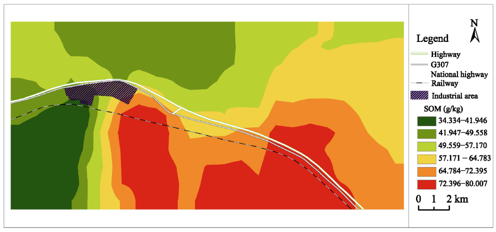

Figure 5 Spatial distribution of soil available K content

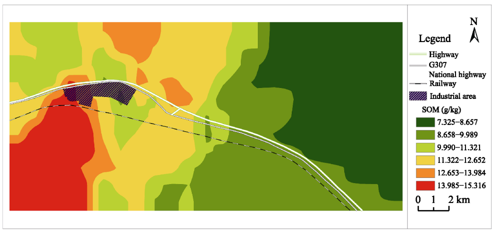

Figure 6 Spatial distribution of soil organic matter content

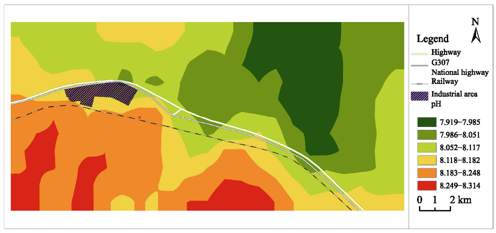

Figure 7 Spatial distribution of soil pH

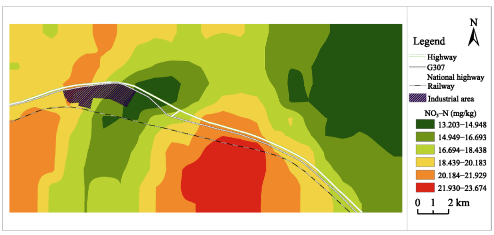

Figure 8 Spatial distribution of soil nitrate nitrogen content

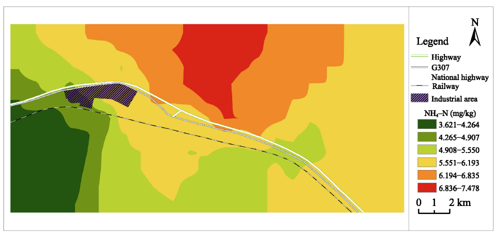

Figure 9 Spatial distribution of soil ammoniacal nitrogen content

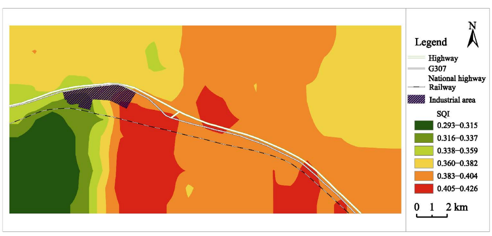

Figure 10 Spatial distribution of soil quality

In summary, the spatial distribution of soil quality indicators in the study area follow a trend. In this study, the highway was taken as a demarcation point, with soil pollution increasing to the north of it and decreasing in the south. Therefore, we see the difference across the spatial distribution of the soil-quality indicators in the study area.

5 Discussion and Conclusion

The measured dataset of surface-soil quality in the desert steppe under industrial activities included N, TP, AP, AK, SOM, NH_4-N, and NO_3-N concentrations, as well as the pH of the surface soil from the study area. The research is calculated by the correlation coefficient method and the membership function method, and the spatial interpolation graph was combined to understand the soil quality distribution status more comprehensively in the study area. This study area was located in the northern desert steppe area, with year-round aridity, low rainfall, serious soil desertification, lack of water and nutrients, low soil water holding capacity, and low soil N, P, SOM, and other nutrients. The industrial activities in the region have further reduced the soil quality of the desert steppe. The soil quality indicators in this dataset are helpful to understand the soil quality of desert steppe under industrial activities. This study provides a reference for the conservation of the fragile desert steppe ecosystem in China.

Author Contributions

Mi, W. B. and Mi, N. designed the algorithms of dataset. Xu, Z. and Tian, Y. contributed to the data processing, analysis and wrote the data paper.

Conflicts of Interest

The authors declare no conflicts of interest.

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