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In Situ Dataset Development of Soil Nutrients in the Urban Green Belts of Dezhou City

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Abstract: To investigate the soil-related causes of poor vegetation growth in the urban green belts of Dezhou City, a systematic soil sampling survey of the green belts in the urban core area was conducted in June 2024, including Tianqu Road, Dongfeng Road, East and West Chahe Avenue, Changhe Avenue, and Hubin Avenue. A total of 23 multi-profile soil samples were collected at different depths (0−20, 20−40, 40−60, 60−80, and 80−100 cm). The study systematically determined the 6 key soil parameters of pH, salinity, organic matter, available nitrogen, available phosphorus, and available potassium using standardized analytical methods, including a pH meter, the oven-drying gravimetric method, and the externally heated dichromate oxidation method. The dataset includes: (1) the geographical locations and surface vegetation data of the sampling sites; (2) measured soil nutrient data from the greenbelt, including stratified values of 6 fertility indicators: pH, salinity, organic matter, available N, available P, and available K; (3) statistical characteristics of soil nutrient data; (4) mean membership values of different soil indicators across soil layers and roads; (5) soil fertility evaluation index across different layers and roads; (6) data used for calculation. The dataset is archived in .shp and .xlsx formats, and consists of 8 data files with data size of 191 KB (Compressed into one file with 160 KB).

Keywords: soil properties; IFI; membership function; green belt

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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.2025.03.07.V1.

1 Introduction

In recent years, the rapid acceleration of urbanization has exacerbated urban environmental problems[1], and the ecological service function of urban green space has become particularly important. As a key component of urban green space, green belts can not only

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[2] Hu, H. Y., Li, B. B. *In situ* dataset of soil nutrients in urban green belts of Dezhou City, China (2024) [J/DB/OL]. *Digital Journal of Global Change Data Repository*, 2025. https://doi.org/10.3974/geodb.2025.03.07.V1.

alleviate the visual monotony of the urban landscape and enhance the city's aesthetic appeal[2], but they also help to reduce road dust and air pollution[3], and play a crucial role in improving the urban ecological environment, enhancing resident's quality of life, and mitigating the effects of climate change in urban areas.

As the core component of green belts, the growth status of plants directly determines the effectiveness of ecological services. Soil quality is a key factor that restricts the healthy growth of green plants[4–9], studies in many cities in China have revealed common problems in various green belts, such as soil compaction, lack of organic matter, nutrient imbalances, and heavy metal pollution[10–15], which seriously restricts the ecological functions of vegetation. The soil nutrient supply capacity can be quantified through soil fertility evaluation[16], and commonly used methods such as the Nemero index method, the membership function method, and principal component analysis[17–19]have been used to determine the fertility characteristics of greenbelts in different cities. It has subsequently been reported that green areas in the central urban area of Jianyang are limited by a lack of organic matter and total nitrogen[20], Changchun is limited by total phosphorus and nitrogen as well as by nutrient supply capacity constraints[13], and the Nansha district of Guangzhou is constrained by nutrient supply capacity and available P[14]. These findings highlight the unique soil characteristics and fertility profiles of each city. Therefore, it is necessary to accurately understand the soil quality status in urban green areas. This will help to formulate appropriate measures to improve the greening effect of the city, and is of great significance in the construction of green spaces.

In recent years, Dezhou City has actively promoted the development of an ecological garden city; however, the frequent instances of poor plant growth and mortality in green belts have exposed shortcomings in soil quality management. Previous studies have focused on developed cities in the east of China, while there have been few systematic soil surveys in cities in the northern plains, making it difficult to establish a solid foundation for localized improvement. In this study, we selected a typical green belt in Dezhou City and measured pH, salinity, organic matter, and available nutrient indexes through stratified sampling, combined with the affiliation function method, to comprehensively evaluate soil fertility and analyze the spatial differentiation of nutrients. The aim was to determine the causes of the soil degradation that affects plant growth and provide data support for optimizing green space management strategies. The results of this study will supplement the soil quality database for northern urban green belts, providing practical support for the construction of ecological cities in the Huanghuaihai Plain.

2 Metadata of the Dataset

The metadata of the *In situ* dataset of soil nutrients in urban green belts of Dezhou City, China (2024)[21] is summarized in Table 1. It includes the dataset full name, short name, authors, year of the dataset, data format, data size, data files, and data sharing policy, etc.

3 Methods

3.1 Study Area

Dezhou City is located in the northwestern part of Shandong Province, with a longitude of 115°45′–117°36′E, latitude of 115°45′–117°36′N, elevation of 21 m above sea level, and a

Table 1 Metadata summary of the dataset

Items	Description
Dataset full name	*In situ* dataset of soil nutrients in urban green belts of Dezhou City, China (2024)
Dataset short name	SoilNutrientsUrbanGreenBeltsDezhou
Authors	Hu, H. Y., Institute of Geographic Sciences and Natural Resources, Chinese Academy of Sciences, huhongyu449@foxmail.com Li, B. B., Institute of Geographic Sciences and Natural Resources, Chinese Academy of Sciences, libinbin@igsnrr.ac.cn
Geographical region	Decheng District, Dezhou City, China
Year	June 2024
Data format	.xlsx, .shp
Data size	191 KB (compressed into a 160 KB file)
Data files	(1) The geographical locations and surface vegetation data of the sampling sites; (2) measured soil nutrient data from the greenbelt; (3) statistical characteristics of soil nutrient data; (4) mean membership values of different soil indicators across soil layers and roads; (5) soil fertility evaluation index across different layers and roads; (6) data used for calculation
Foundation	National Natural Science Foundation of China (42130713)
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	(1) *Data* are openly available and can be freely 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. (4) If *Data* are used to compile new datasets, the “ten percent principle” should be followed, such that the *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[22]
Communication and searchable system	DOI, CSTR, Crossref, DCI, CSCD, CNKI, SciEngine, WDS, GEOSS, PubScholar, CKRSC

total area of 10,356 km^2. The area belongs to the alluvial plain of northwestern Shandong in the lower reaches of the Yellow River, with a flat terrain, and the general trend of the area slopes gently from the southwest to northeast. The soil parent material is Yellow River alluvial deposits, which are dominated by saline tidal soils, and the topsoil texture is a light-medium loam. The region has a warm-temperate semi-humid monsoon climate, with a multiyear average temperature of 13.2 ℃ and average rainfall of 538 mm.

3.2 Data Collection

The green areas in the main part of Dezhou City are relatively concentrated and are mainly distributed in the areas of Tianqu Road, Dongfeng Road, Chahe East Avenue, Chahe West Avenue, Changhe Avenue, and Hubin Avenue. They contain a wide variety of green plants, mainly trees, shrubs, and herbaceous plants, such as ash, tamarisk, acacia, moon season, begonias, forsythia, maitake, and iris. Soil samples were collected from depths of 0−20, 20−40, 40−60, 60−80, and 80−100 cm, respectively. The spatial distribution of the soil sample collection points is shown in Figure 1.

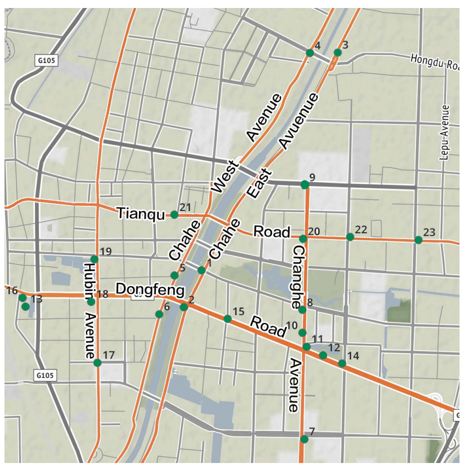

Figure 1 Distribution map of the sampling points in the green belt of Dezhou City

Air-dried soil samples were ground and sieved (pore sizes of 2 and 0.25 mm, respectively, to determine the physicochemical properties of the soil. The soil indicators analyzed in this study were pH, salinity (g/kg), organic matter (g/kg), available N (mg/kg), available P (mg/kg), and available K (mg/kg). The soil pH was determined using a pH meter (PB-10). Soil salinity was measured by the oven-drying method. Soil organic matter content was analyzed via the potassium dichromate oxidation-external heating method. Available N was quantified using the alkali hydrolysis diffusion method. Available P was determined by flow injection analysis and available K was assessed via flame photometry[23].

3.3 Soil Fertility Evaluation Methods

3.3.1 Evaluation of Single Indicators of Soil Properties

The 6 indicators of soil pH, salinity (g/kg), organic matter (g/kg), available P (mg/kg), available N (mg/kg), and available K (mg/kg) were evaluated and graded according to The second national soil survey: soil nutrient grading standards[24].

Using the grading standards, the 6 indices were evaluated and graded. Differences in the indices were compared between different soil layers and roads.

3.3.2 Soil Fertility Evaluation

(1) Calculation of weights

The correlation between the soil indicators was calculated, and the weight value was calculated through the correlation coefficient with the following formula:

$$\mathrm{W}i=\frac{riAvg}{\Sigma riAvg} \tag{1}$$

where, Wi is the weight of an indicator, and $riAvg$ is the average value of the correlation coefficient between indicator i and other indicators.

(2) Membership function model

Based on The second national soil survey: soil nutrient grading standards[24], the corresponding turning point value intervals of the membership function were calculated according to the content of each indicator. The formula for calculating the membership function based on these intervals was established, enabling the membership value of each indicator to be calculated. The membership function of soil pH was the parabolic type, and therefore the formula used was Equation 2. The membership function of soil salinity (g/kg), organic matter (g/kg), available N (mg/kg), available P (mg/kg), and available K (mg/kg) was the S-type, and therefore formula used was Equation 3.

$$f(x)\begin{cases} 1.0-\dfrac{0.9(x-x3)}{x4-x3} & x3<x<x4 \\ 1.0 & x2<x<x3 \\ \dfrac{0.9(x-x1)}{(x2-x1)}+0.1 & x1<x<x2 \\ 0.1 & x\leqslant x1 \text{ or } x\geqslant x4 \end{cases} \tag{2}$$

$$f(x)\begin{cases} 1.0 & x\geqslant x2 \\ \dfrac{0.9(x-x1)}{x2-x1}+0.1 & x1<x\leqslant x2 \\ 0.1 & x\leqslant x1 \end{cases} \tag{3}$$

where, x represents the measured values of various soil nutrient indicators at the sampling point, while $x1$, $x2$, $x3$, and $x4$ denote the graded standard values of nutrients from the Second National Soil Survey.

(3) Calculation of the fertility evaluation index

The soil fertility evaluation index can characterize the fertility level of the soil, the specific formula is as follows:

$$\text{IFI}=\sum_{i=1}^{n} WiFi \tag{4}$$

where, n is the measured sample size of an index, Wi is the weight value of the i_{th} index, Fi is the membership degree value of the i_{th} index, and IFI is the fertility evaluation index. The range of the interval is 0–1, and the closer the value is to 1, the better the quality of the soil.

3.4 Data Processing

The SPSS20.0 software was used for the statistical descriptions and to conduct an analysis of variance (ANOVA) of soil pH, salinity (g/kg), organic matter (g/kg), available N (mg/kg), available P (mg/kg), and available K (mg/kg) content of green belts in the layers-dimension and road-dimension. Origin8.0 was used to construct graphs of these 6 indicators.

4 Data Results

4.1 Dataset Composition

The *In situ* dataset of soil nutrients in urban green belts of Dezhou City, China (2024) includes: (1) the geographical locations and surface vegetation data of the sampling sites; (2) measured soil nutrient data from the greenbelt, including stratified values of six fertility indicators: pH, salinity, organic matter, available N, available P, and available K; (3) statistical characteristics of soil nutrient data; (4) mean membership values of different soil indicators across soil layers and roads; (5) soil fertility evaluation index across different layers and roads; (6) data used for calculation. The descriptions for each field are shown in Table 2.

Table 2 The descriptions for each field of the dataset

Field names	Data content	Data description
Sampling Point ID	Sampling point ID	A unique identifier for each soil sampling point
Road name-CN	Road name (Chinese)	The Chinese name of the road
Road name-EN	Road name (English)	The English name of the road
Landscape plants-CN	Landscape plants (Chinese)	The Chinese name of the landscape plants
Landscape plants-EN	Landscape plants (English)	The English name of the landscape plants
Longitude	Longitude	The geographical longitude coordinate
Latitude	Latitude	The geographical latitude coordinate
Depth	Sampling depth	The soil sampling depth (cm)
pH	pH	The pH of the sampled soil
Salinity (g/kg)	Soluble salt content	The soluble salt content in the sampled soil (g/kg)
Organic matter (g/kg)	Organic matter content	The organic matter content in the sampled soil (g/kg)
Available N (mg/kg)	Available N content	The available N content in the sampled soil (mg/kg)
Available P (mg/kg)	Available P content	The available P content in the sampled soil (mg/kg)
Available K (mg/kg)	Available K content	The available K content in the sampled soil (mg/kg)

4.2 Data Results

4.2.1 Properties of the Different Soil Layers within Green Belts

As shown in Figure 2, the pH of the green belt soils (0–100 cm) in the urban area of Dezhou ranged from 7.8 to 9.5, and the mean values of soil pH in the different soil layers exceeded 8.5, indicating that the green belt soils were strongly alkaline. Soil salinity (0–100 cm) was in the range of 0.4–14.02 g/kg, with an average value of 1.84–4.06 g/kg, indicating that the green belt soil was moderately saline. Dezhou City is located in the northwestern part of Shandong Province, which has long been affected by the changes in the water systems of the Yellow River, Huaihe River, and Haihe River. Frequent flooding, river diversions, and seawater inversions have led to the formation of saline soils[25]. In general, the pH range of soil suitable for plant growth is 6.5–7.5, and the salt content needs to be <0.1%[26], while the soil in the green belts of downtown Dezhou clearly exceeds this range, which may lead to plant root damage and affect the absorption of water and nutrients. Therefore, measures such as freshwater leaching for desalination and gypsum application should be implemented to regulate soil pH and salinity, thereby improving the soil environment.

The soil organic matter content in the green belt in the urban area of Dezhou City was classed as extremely poor[24]. Studies have shown that salinization destroys soil aggregate structure, reduces soil water holding capacity and nutrient retention capacity, and accelerates organic matter degradation and loss[27]. Furthermore, in the management of urban green belts, the infrequent application of organic fertilizers and prompt removal of dead leaves and branches results in a reduced input of organic matter. This explains the low organic matter content of soils in the urban green belts in Dezhou City[6,28]. To improve this situation, the input of organic fertilizer and green manure should be increased appropriately, while management measures to improve the soil organic matter level should be optimized.

The mean available N in the 0–20 cm soil layer in the urban green belt of Dezhou City was 69.47 mg/kg, which was classed as moderate, while the mean available N in the rest of the soil layer was classed as poor or below. It therefore needs to be enhanced to improve the

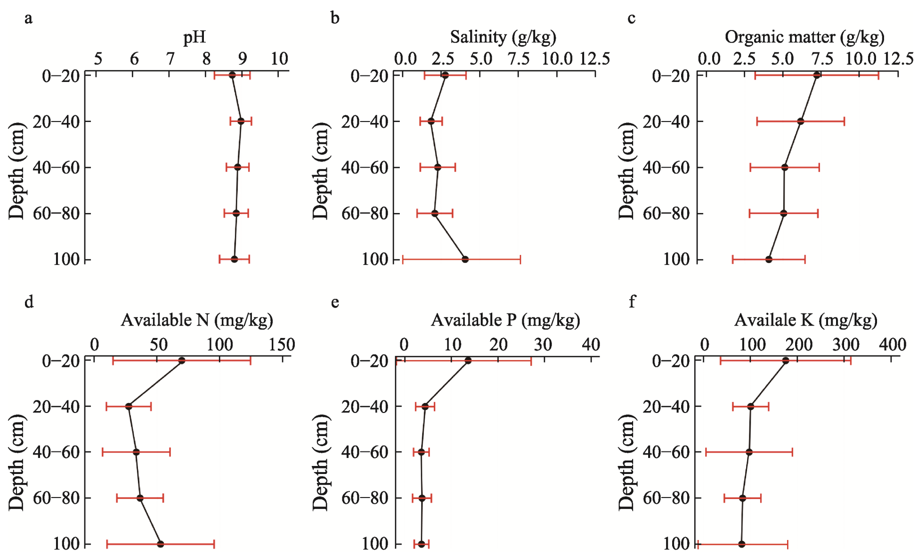

Figure 2 Variations in soil properties across different soil depth layers

soil fertility[29]. However, the low soil organic matter content in the green belts of urban areas in Dezhou City leads to an insufficient nitrogen supply capacity. The mean soil available P at 0−20 cm was 13.66 mg/kg, which was classed as moderate, while the remaining soil layers had only 3.62−4.43 mg/kg of available P, which was classed as poor. Phosphorus is an important nutrient for plant growth. It is involved in photosynthesis, energy transfer, and antioxidant synthesis, especially in saline soils, where salinity further reduces the P uptake capacity of plants[30–32]. Therefore, the lack of available N and P in green belt soils in Dezhou City should be increased by applying more organic fertilizers and deeper applications of chemical fertilizers. The average available K in the 0−20 cm soil layer was 175.73 mg/kg, which was classed as abundant, and the average value of 101 mg/kg in the 20−40 cm soil layer was classed as rich. Compared with the available N and P, the available K was relatively abundant. The focus should therefore be on the supplementation of N and P.

4.2.2 Soil Properties of Green Belts Along Different Roads

As shown in Table 3, the mean soil pH in green belts along different roads ranged from 8.7 to 9.05, with the highest mean soil pH occurring in Chahe West Avenue (9.05) followed by Dongfeng Road (8.9), Tianqu Road and Changhe Avenue (both 8.82), and Chahe East Avenue and Hubin Avenue (both 8.7). There were no significant differences in soil pH among the different roads. The ANOVA results showed that the soil salt content of Chahe East Avenue was significantly different from that of Changhe Avenue and Hubin Avenue.

According to The Second National Soil Survey: Soil Nutrient Grading Standards, the soil organic matter content in the green belt in the urban area of Dezhou City was poor overall (4.19−6.43 g/kg), and there were no significant differences among the roads. The available N was poor (23.3−52.9 mg/kg), with significant differences only between East and West Chahe Avenue. The available P decreased in the order of Dongfeng Road (8 mg/kg, moderate) > Tianqu Road (7.55 mg/kg, moderate) > Chahe West Avenue > Hubin Avenue > Changhe Avenue > Chahe East Avenue (all poor). The available K was highest on Tianqu Road (170 mg/kg, rich), followed by Dongfeng Road (124.87 mg/kg), Chahe West Avenue (121.11 mg/kg). Tianqu Road differed significantly from Chahe East Avenue and Changhe Avenue.

Because the plants in the green belts of urban areas in Dezhou City are mainly trees and shrubs with deep root systems, and the soil available N and P levels are low in deep soils, this may impose limitations on the long-term growth of plants. Therefore, organic fertilizers and deep-applications of chemical fertilizers should be targeted in combination with road differentiation to improve soil fertility and optimize the greening effect.

Table 3 Differences in the chemical properties of soil in the green belts of different roads

	pH	Salinilty (g/kg)	Organic matter (g/kg)	Available N (mg/kg)	Available P (mg/kg)	Available K (mg/kg)
Chahe East Avenue	(8.7±0.45)b	(3.2±0.85)a	(4.19±3.33)a	(52.9±35.41)a	(3.27±1.52)ab	(104.3±52.51)bc
Chahe West Avenue	(9.05±0.34)a	(2.92±1.17)ab	(5.63±2.08)a	(23.2±8.33)b	(4.9±2.13)ab	(121.11±51.88)abc
Dongfeng Road	(8.9±0.34)ab	(2.61±3.15)ab	(5.98±2.77)a	(47.11±47.45)a	(8±11.14)a	(124.87±95.33)ab
Hubin Avenue	(8.7±0.21)b	(1.92±0.89)b	(6.43±1.61)a	(33.82±20.68)ab	(4.5±1.53)ab	(114.75±57.66)abc
Tianqu Road	(8.82±0.33)ab	(2.93±1.71)ab	(5.82±3.33)a	(43.91±30.15)ab	(7.55±13.79)ab	(170±110.02)a
Changhe Avenue	(8.82±0.31)ab	(1.94±0.58)b	(6.22±2.29)a	(31.93±17.37)ab	(3.64±1.68)ab	(81.52±24.27)bc

Note: a, b, and c indicate significant differences at the 0.05 level.

4.2.3 Comprehensive Evaluation of Soil Fertility

The fertility composite index of the top soil layer (0–20 cm) of the green belt in the urban area of Dezhou was 0.54, which was classed as relatively poor (Table 4). The average membership degree values of soil pH and organic matter were 0.1 and 0.17, respectively (Table 5). These values were significantly smaller than the membership degree values of the other indexes, which indicates that soil pH and organic matter were the limiting factors of soil fertility. The composite index of fertility of the lower soil layers (20–40, 40–60, 60–80, and 80–100 cm) ranged from 0.1 to 0.3, which was classed as poor (Table 4). The limiting factors of soil fertility were different for the different soil layers (Table 5), with soil pH and organic matter being the main limiting factors.

The soil fertility index of different roadside green belt soils was in the range of 0.12–0.35, which was classed as poor (Table 6). The fertility-limiting factors of different roadside green belt soils were slightly different (Table 7). Soil pH and organic matter, with an average membership value of 0.1, were the main limiting factors for soil fertility for all roadside green belts.

Table 4 Soil fertility evaluation index in different soil layers

Soil layer (cm)	0–20	20–40	40–60	60–80	80–100	0–100
IFI	0.54	0.10	0.12	0.12	0.30	0.24
Level	Relatively poor	Poor	Poor	Poor	Poor	Poor

Table 5 Average membership degree of soil indicators in different soil layers

Soil layer (cm)	Average membership degree					
	pH	Salinity	Organic matter	Available N	Available P	Available K
0–20	0.10	0.33	0.18	1.00	0.88	0.78
20–40	0.10	0.10	0.11	0.10	0.10	0.11
40–60	0.10	0.18	0.10	0.19	0.10	0.10
60–80	0.10	0.12	0.10	0.28	0.10	0.10
80–100	0.10	0.72	0.10	0.77	0.10	0.10
0–100	0.10	0.28	0.10	0.51	0.17	0.17

Table 6 Soil fertility evaluation index in different roads

	Chahe East Avenue	Chahe West Avenue	Dongfeng Road	Hubin Avenue	Tianqu Road	Changhe Avenue
IFI	0.26	0.18	0.32	0.15	0.35	0.12
Level	Poor	Poor	Poor	Poor	Poor	Poor

Table 7 Average membership degree of soil indicators in different roads

Road	Average membership degree					
	pH	Salinity	Organic matter	Available N	Available P	Available K
Chahe East Avenue	0.10	0.46	0.10	0.79	0.10	0.14
Chahe West Avenue	0.10	0.38	0.10	0.10	0.10	0.29
Dongfeng Road	0.10	0.28	0.10	0.61	0.37	0.32
Hubin Avenue	0.10	0.10	0.13	0.21	0.10	0.23
Tianqu Road	0.10	0.38	0.10	0.52	0.33	0.73
Changhe Avenue	0.10	0.10	0.11	0.16	0.10	0.10

5 Conclusion

Based on measured data, this dataset systematically compiled the main nutrient indicators of green belt soils in the urban area of Dezhou City, including pH, salinity, organic matter, available N, available P, and available K. Through a statistical analysis and evaluation of the membership function of the measured data, the soil nutrient status of the soil in the urban green belts of Dezhou City was determined for different soil layers and roads. The following conclusions were drawn.

(1) The pH of the soil in the green belt in the urban area of Dezhou City was >8.5, indicating a strongly alkaline soil. The mean soil salinity was 2.6 g/kg, and the salinization level of the different roads was classed as mild to moderate.

(2) The mean organic matter content was 5.53 g/kg, which was classed as poor. The overall soil available N and P were classed as poor, and soil available K was classed as relatively rich. Soil organic matter and the available N, P, and K were significantly lower in the lower soil layers than in the surface soil.

(3) The fertility level of the green belt soil (0−100 cm) in the urban area of Dezhou City was poor. Both soil pH and organic matter were limiting factors for soil fertility. It was therefore recommended to implement targeted measures, such as salt leaching, the application of chemical amendments (e.g., gypsum), and the increased deep placement of organic and chemical fertilizers.

Author Contributions

Hu, H. Y. conducted the overall design of the dataset. Wang, Z. B. and Li, B. B. collected and processed the soil nutrient data from the greenbelts in urban areas of Dezhou. Hu, H. Y. designed the evaluation model. Fan, Z. X. and Li, B. B. verified the accuracy and authenticity of the data. Hu, H. Y. and Wang, Z. B. wrote the data paper.

Conflicts of Interest

The authors declare no conflicts of interest.

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