

Research Article

Soil Chemical Properties under Various Land-Use Types in the Karst Area with a Case Study in Shibing County of China

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The effects of different land-use types on the pH, organic carbon, total nutrient, and available nutrients of soil in the 0–30 cm and 30–60 cm layers were studied using the gray relational analysis method. The research area is located in Baiduo village in the dolomite karst region and Shiqiao village in the limestone karst region of Shibing County, Guizhou Province, China. The land-use types investigated included shrubland, forest, grass slope, dryland, paddy field, pear orchard, and flue-cured tobacco field. The contents of organic carbon, total nitrogen, alkaline hydrolysable nitrogen, and available potassium, as well as the pH of the soil in the dolomite shrubland, were higher than those in the limestone shrubland. The total potassium, total phosphorus, and available phosphorus contents of soil in the limestone shrubland were higher than those in the dolomite shrubland. Among the four types of land-use most strongly affected by human activities (paddy field, dryland, flue-cured tobacco field, and pear orchard), the nutrient contents (except potassium in the upper soil layer) were higher than those in the lower layer. The differences in nutrient contents between upper and lower layers were relatively small in the dryland and the pear orchard, whereas they were large for the paddy field and flue-cured tobacco field. The gray relational degree of various land-use types decreased in the following order: dolomite shrubland > forest > grass slope > pear orchard > limestone shrubland > paddy field > dryland > flue-cured tobacco field. The dolomite shrubland had the best soil quality, while the flue-cured tobacco field had the worst. Of the four types of land use most strongly affected by human activities, pear orchard had the best soil quality. This study can provide reference for soil nutrient management and sustainable management in karst areas.

1. Introduction

There are many mountains but a few agricultural lands in the karst areas [1, 2]. The soil quality in karst areas is usually poor, and there are serious soil erosion problems, leading to a conflict between human activity and land preservation goals [3]. Moreover, the soil quality in the karst areas is degrading due to unsustainable land use [4]. The soil degradation problems are getting increasingly serious and difficult to deal with [5]. Human activities may change the properties and environmental conditions of soil [6, 7], affecting the level of soil productivity as well as the path and direction of ecological restoration in the region [8].

Researchers have studied the effects of land-use types on the physical and chemical properties of soil. For example, Li et al. [9] evaluated the soil quality status developed in limestone in the karst valley area by calculating the soil degradation index. Yu et al. [10] evaluated the soil quality of a *Zanthoxylum bungeanum* plantation at different altitudes in a limestone karst dry and hot valley area based on 27 factors as basic indicators. Liu et al. [11] described the soil fertility characteristics of different land-use types in the karst peak-cluster and depression area. Shamsheer et al. [12] evaluated the soil organic carbon stock dynamic across various land uses at different altitudes in the Bagrot valley, Northern Karakoram. In addition, Zhang et al. [13]

comprehensively evaluated the soil quality of 10 forest stands using the factor analysis method. Zhang et al. [14] comprehensively evaluated the soil fertility under 11 different fertilization modes using the principal component analysis method. La et al. [15] used the fuzzy comprehensive evaluation method to comprehensively evaluate the soil fertility in tobacco fields. Studies have shown that appropriate land-use types can improve soil structure, enhance soil resistance to environmental changes, and improve soil quality [16]. The abovementioned methods reveal the effects of land-use types on soil chemical properties to a certain extent, but the meaning of the composite evaluation function of any single soil property index remains unclear. In addition, the actual connections between factors are not typically considered and large amounts of calculations are required.

Previous studies mainly focused on limestone areas, and there were few reports on the effects of different land-use types on soil chemical properties in dolomite regions [17]. Dolomites have a wide distribution, a thin soil layer, a high gravel content, a slow rate of soil formation, and low amounts of soil-forming substances. In terms of research methods, the gray relational analysis method, which requires only a small amount of calculation, produces results that are closely consistent with the results of qualitative analysis, is useful for comprehensive evaluation [18, 19], and has rarely been applied to the analysis of physical and chemical properties of soil in karst areas. Therefore, it is necessary to study the soil chemical properties under different land-use types in the dolomite karst areas using gray relational analysis.

Two villages (Baiduo village and Shiqiao village) in the buffer zone of Shibing Karst World Natural Heritage Property, located in Shanmuhe catchment in Shibing County of Guizhou Province, China, were selected as the study area. Dolomite karst in the study area is an outstanding representative of the world. The gray relational method was used to analyze the effects of different land-use types on soil chemical properties, and the status of soil quality was discussed. The following research questions were considered: (1) How soil chemical properties change with the lithology of the parent rock? (2) How soil chemical properties change with soil depth? (3) The status of soil quality under different land-use types. This study is of great significance to the protection and sustainable development of Shibing Karst, to soil quality research, and soil nutrient management in other karst areas elsewhere in the world.

2. Materials and Methods

2.1. Overview of the Research Area. The research area is located in Baiduo and Shiqiao villages in the Shanmuhe catchment and the buffer zone of Shibing Karst World Natural Heritage Property, in eastern Guizhou Province, China ($27^{\circ}05'49''-27^{\circ}13'59''\text{N}$, $108^{\circ}01'34''-108^{\circ}09'32''\text{E}$; Figures 1 and 2). It is located on the mountain slope, where the eastern margin of the Yunnan-Guizhou Plateau transits to the low hills of western Hunan, and the terrain gradually decreases from west and northwest to east and southeast.

The highest elevation is 1615 m, and the lowest is 520 m. The total area is 28295 ha [20]. The thickness of sedimentary rocks in the area is 2520 m [21]. The area is basically composed of Cambrian strata, and only a small part of the Sinian, Ordovician, Nanhua, and Qingbaikou systems are found in the northern part of the research area. The forest ecosystem of the research area includes coniferous forests dominated by *Pinus massoniana*, broad-leaved forests dominated by Fagaceae, Polygonaceae, and Magnoliaceae, coniferous and broad-leaved mixed forests composed of *Pinus massoniana* and *Quercus aliena*, and shrubs dominated by *Neosinocalamus affinis* and *Ilex metabaptista*. The stratigraphic lithology developed in Baiduo is mainly the dolomites of the Cambrian Loushanguan and Shilengshui Formation. The rocks are broken, and the lithofacies are flat. The internal suture structure and fracture were developed [22]. The lithology of the strata developed in Shiqiao is the argillaceous dolomitic limestone of the Gaotai and Qingxudong Formation [23]. There are exposed rocks, and the soil is not continuous. The linear distance between the two regions is 14.5 km. The soil type is mainly limestone soil formed by limestone and dolomite weathering. There is a mid-subtropical monsoon humid climate in both regions. The average annual precipitation is 1220 mm, and the annual average temperature is 16°C .

2.2. Sample Collection and Processing. In April 2018, the pear orchard, flue-cured tobacco field, and limestone shrubland (shrubland L) were selected as sampling sites in Shiqiao based on literature research and field surveys. In Baiduo, five types of land such as paddy field, grass slope, dryland, dolomite shrubland (shrubland D), and forest were selected as sampling sites. The area of the plot was $10\text{ m} \times 10\text{ m}$. The main characteristics of the sites are shown in Table 1, and locations of the sampling sites on the geological map and land-use map are shown in Figures 3 and 4, respectively. The thicknesses of the soil in pear orchard, flue-cured tobacco field, paddy field, and dryland were more than 60 cm. Samples from the 0–30 cm soil layer (upper), which is strongly affected by human cultivation activities as well as the 30–60 cm layer (lower), which is less affected by human activities and maintains the natural soil deposit before planting, were collected. The thicknesses of the soil in grass slope and shrubland were less than 30 cm, and the soil above the bedrock was collected by soil drilling. Six parallel samples were selected for each land-use type, and a total of 72 soil samples were collected. After the soil samples were taken back to the laboratory, debris such as gravel, roots, and animal residues were removed from the soil samples which were then air-dried, ground through 2 mm and 0.15 mm sieves, and placed in glass bottles for storage.

2.3. Sample Measurement and Data Processing

2.3.1. Sample Measurement. The soil analysis method of Bao SD [24] was used in this study. The pH of the soil was measured by the electrode potential method. The soil organic carbon (SOC) was measured by the external-heat



FIGURE 1: The location of Shibing Karst World Natural Heritage Property, in eastern Guizhou Province, China.

potassium dichromate oxidation method, and total nitrogen (TN) was determined by the semi-micro-Kjeldahl method (flow injection method). The total phosphorus (TP) was assessed by the sodium hydroxide melt-molybdenum and antimony-antichromogenic-ultraviolet spectrophotometry method, and total potassium (TK) was assessed by the sodium hydroxide melt-atomic absorption method. The alkaline hydrolysable nitrogen (AN) was determined by the alkaline decomposition diffusion method. The available phosphorus (AP) was measured by the sodium bicarbonate extracting molybdenum and antimony-anticolorimetric method, and the available potassium (AK) was determined by the neutral ammonium acetate extraction and flame photometer method.

2.3.2. Data Processing. Using the principles and methods of gray system theory, the gray relational analysis and correlation ordering of soil chemical properties of different land-use types were carried out. The maximum values of TN, AN, TP, AP, TK, AK, and SOC were selected as reference series. The principle of dimensionless processing was 0–10 (data larger than 10 were all divided by 100, and data smaller than 10 remained unchanged so that all data were between 0–10). The calculation formula of the correlation coefficient is as follows:

$$\xi_i(k) = \frac{\min_i \min_k |x_0(k) - x_i(k)| + 0.5 \max_i \max_k |x_0(k) - x_i(k)|}{|x_0(k) - x_i(k)| + 0.5 \max_i \max_k |x_0(k) - x_i(k)|}, \quad (1)$$

where $\xi_i(k)$ is the correlation coefficient, $\min_i \min_k |x_0(k) - x_i(k)|$ is the minimum value of the absolute value of the difference between factor k and the subject to be evaluated in the i th sample and $\max_i \max_k |x_0(k) - x_i(k)|$ is the maximum value of the absolute value of the difference between factor k and the referenced factor in the i th sample. The average correlation coefficient of each factor can be obtained based on $\xi_i(k)$. The correlation degree r_i can be calculated as follows $r_i = 1/n * \sum_{i=1}^n \xi_i(k)$. The greater the r_i of the analyzed series, the closer it is to the reference series and the better the effect on improving soil quality.

3. Results

3.1. Effects of Different Land-Use Types on SOC and Soil pH. Figure 5 shows that the SOC content in the upper layer of all land-use types was higher than that in the lower layer. The difference between the SOC content in the two soil layers in flue-cured tobacco field, pear orchard, and dryland was not significant ($P > 0.05$ for all tests), while the difference between the upper and lower layers of the paddy field was significant ($P < 0.05$ for all tests). The difference in soil pH

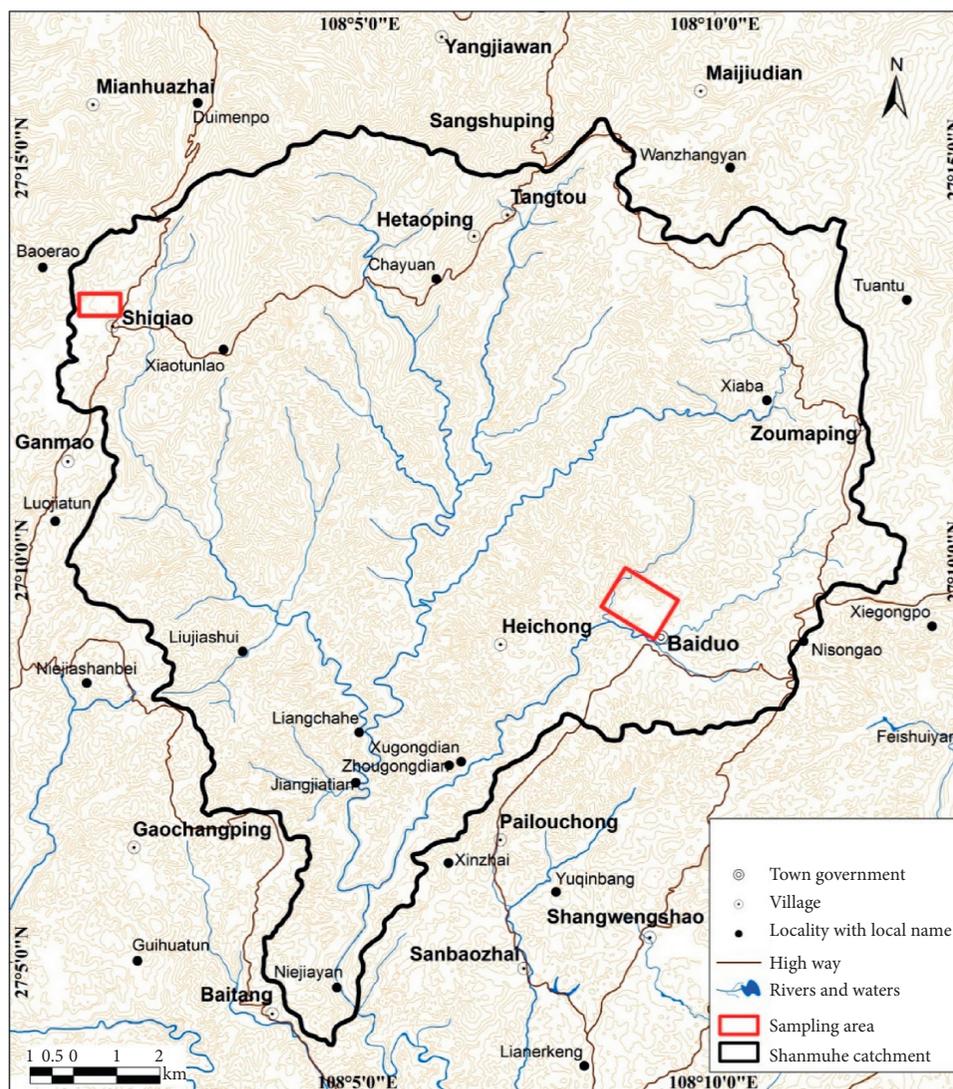


FIGURE 2: Location of the Shanmuhe catchment and sampling area.

TABLE 1: Characteristics of each sampling site.

No.	Land-use type	Altitude (m)	Vegetation	Coverage	Features
1	Pear orchard	1053	Pear tree	0.75	The average height of trees was 1.3 m, and the average age of trees was 4 years. No fruit was observed, and there were low weeds under the forest
2	Flue-cured tobacco field	1064	Flue-cured tobacco	0.20	From 2016 to 2018, flue-cured tobacco was cultivated. The average height of flue-cured tobacco was 10 cm when sampling, and no weeds were observed
3	Limestone shrubland	1071	Mainly <i>Cyclobalanopsis glauca</i>	0.85	The soil was moist. The thickness of the soil layer was 20 cm, and the thickness of the litter layer was 3 cm. Soil animals such as earthworms were found
4	Paddy field	972	Weeds	0.90	It was not yet cultivated, waterless with rice piles, and distributed with weeds such as rat grass, muddy vegetables, and sorghum. Gravel was found in soil
5	Dolomite shrubland	990	Mostly <i>Cinnamomum camphora</i>	0.85	The thickness of the litter layer was 3 cm, and the thickness of the soil layer was 20 cm. The sand content was high, and the soil was dry
6	Grass slope	1061	Mainly ferns and <i>Miscanthus floridulus</i>	1	It was a natural grass slope with a thickness of 15 cm. It was high in grit content. Shrubs were sparsely distributed

TABLE 1: Continued.

No.	Land-use type	Altitude (m)	Vegetation	Coverage	Features
7	Dryland	1043.1	No vegetation	0	The crops planted in 2017 were peppers. The land has been ploughed, and no crops have been planted. No weeds were found
8	Forest	956	Mostly <i>Platycladus</i> and <i>Pinus massoniana</i>	0.90	The thickness of the litter layer was 1.5 cm, and the thickness of the soil layer was 10 cm. The sand content was high, and there were lichens

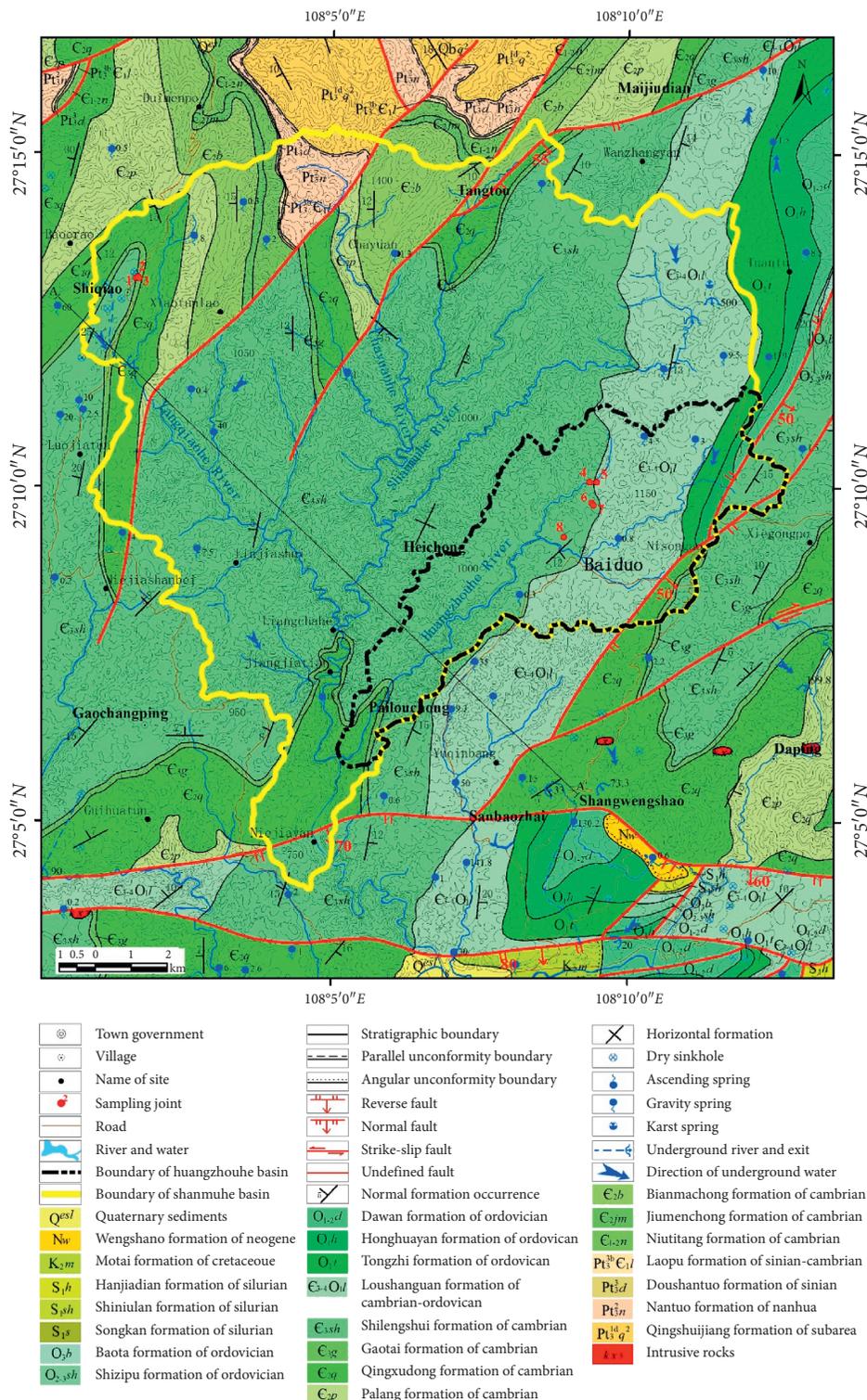


FIGURE 3: The location of the sampling sites on the geological map.

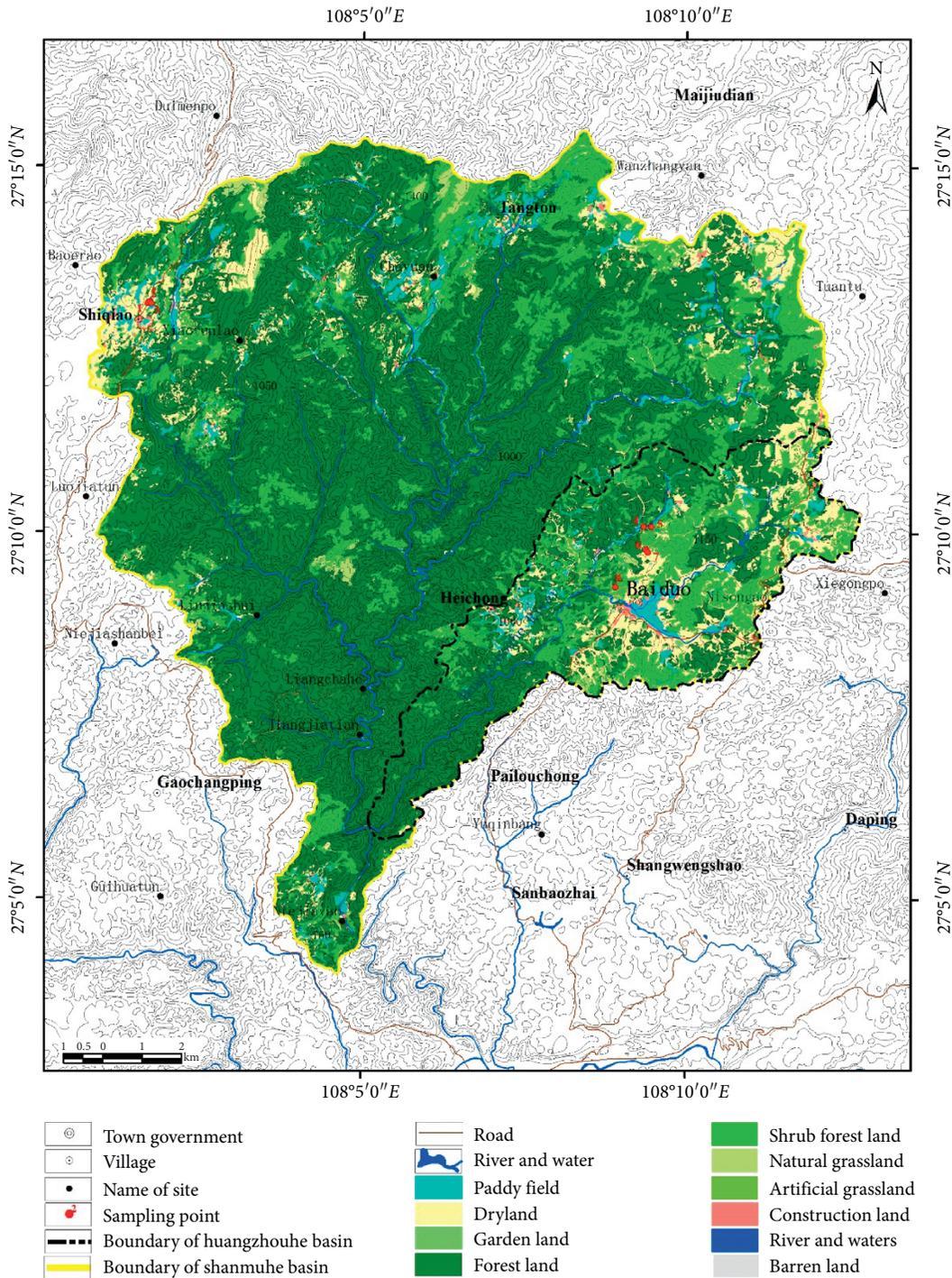


FIGURE 4: The location of the sampling sites on the land-use map.

between the upper and lower soil layers was not significant. The SOC content decreased in the following order under different land-use types: forest > dolomite shrubland > grass slope > paddy field > limestone shrubland > pear orchard > dryland > flue-cured tobacco field, and the SOC contents of the first five land-use types were significantly higher than those of the latter three. The soil pH decreased in the following order: paddy field > pear orchard > grass slope > dolomite shrubland > forest > flue-cured tobacco field > dryland > limestone shrubland.

3.2. Effects of Land-Use Type on Soil Total Nutrients. The TN contents in the upper soil of paddy field, dryland, flue-cured tobacco field, and pear orchard were greater than those of the lower layers, with the coefficient of variation of the upper and lower layers of the paddy field reaching 88.03% and the dryland reaching only 7.46%. Under different land-use types, TN content decreased in the order dolomite shrubland > forest > grass slope > paddy field > limestone shrubland > pear orchard > dryland > flue-cured tobacco field. The soil TP content decreased in the order grass slope > pear

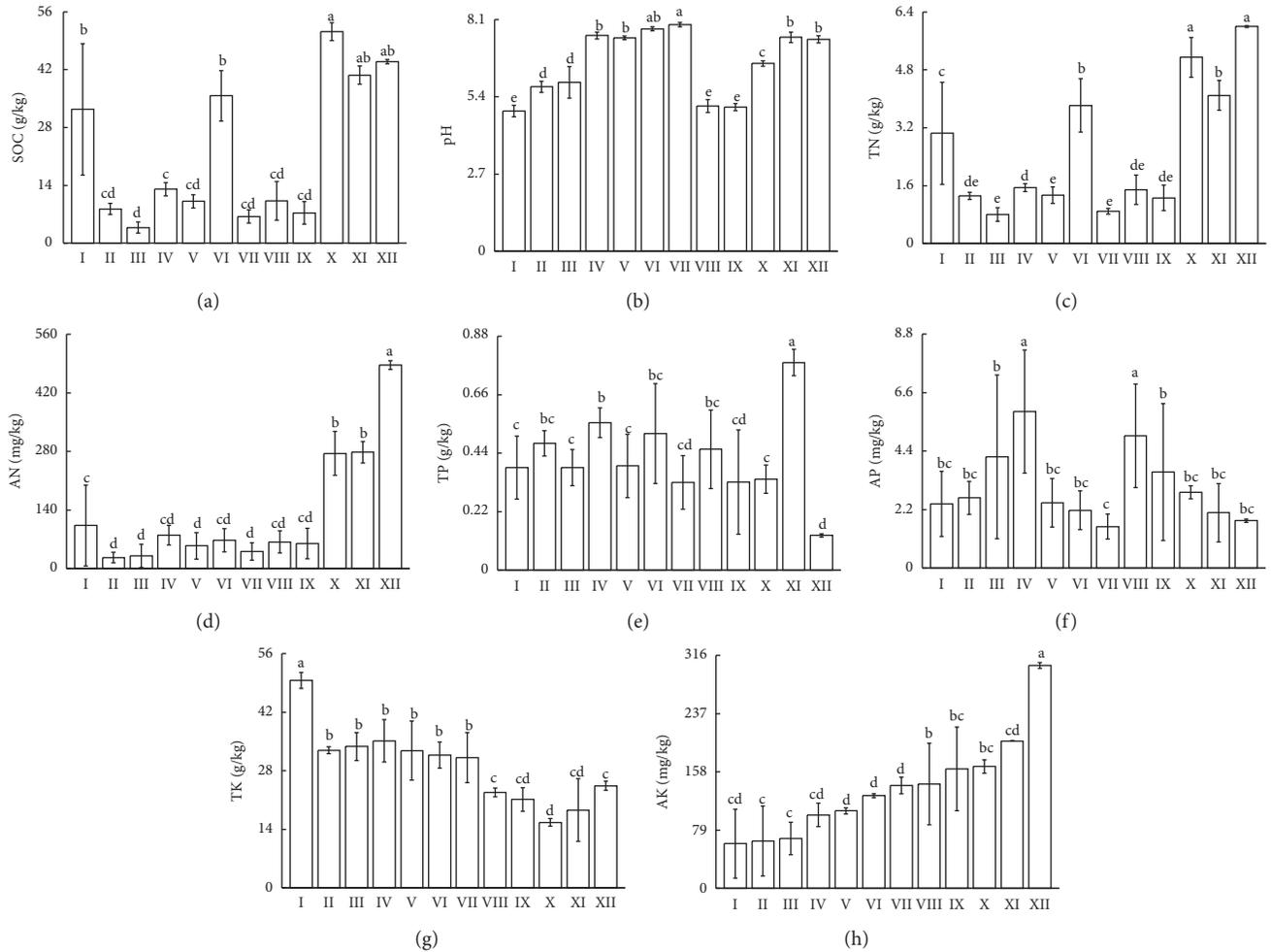


FIGURE 5: Soil pH and element contents under different land-use types. Note I, II, III, IV, V, VI, VII, VIII, IX, X, XI, and XII represent limestone shrubland, upper flue-cured tobacco field, lower flue-cured tobacco field, upper pear orchard, lower pear orchard, upper paddy field, lower paddy field, upper dryland, lower dryland, forest, grass slope, and dolomite shrubland, respectively. Different letters indicate significant differences in land-use types.

orchard > paddy field > flue-cured tobacco field > dryland > limestone shrubland > forest > dolomite shrubland, and the TP content of grass slope was significantly higher than those of other land-use types. The TP contents of the upper soil for all of the land-use types were higher than those of the lower layers, and the difference of TP content in the same soil layer under different land-use types was not significant. There was no significant difference in TK content in different soil layers of paddy field, dryland, pear orchard, and flue-cured tobacco field. The soil TK content decreased in the order limestone shrubland > pear orchard > flue-cured tobacco field > paddy field > dolomite shrubland > dryland > forest > grass slope.

3.3. Effects of Land-Use Type on Soil Available Nutrients. Figure 5 shows that, in the paddy field, dryland, and pear orchard, the AN contents in the upper layer were higher than those in the lower layers, while the flue-cured tobacco field showed the opposite trend. Under different land-use types, the AN content decreased in the order dolomite shrubland > grass slope > forest > limestone shrubland > pear orchard > paddy

field > dryland > flue-cured tobacco field. The soil AN contents in dolomite shrubland, grass slope, and forest were significantly higher than those of the latter five land-use types. The AP contents in the upper soil of paddy field, dryland, and pear orchard were higher than those of the lower layers, while the flue-cured tobacco field showed the opposite trend. The coefficient of variation was the largest for pear orchard in the two soil layers. Under different land-use types, the soil AP content decreased in the order pear orchard > dryland > forest > flue-cured tobacco field > limestone shrubland > paddy field > grass slope > dolomite shrubland. The soil AK content decreased in the order dolomite shrubland > dryland > forest > flue-cured tobacco field > grass slope > limestone shrubland > pear orchard > paddy field. The AK contents in the upper soil layer of dryland, flue-cured tobacco field, and pear orchard were higher than those in the lower layers, while the paddy field showed the opposite trend.

3.4. Gray Relational Analysis of Different Land-Use Types. The diversity of the karst niche at the small scale is complex with a random soil distribution. The relationship between

chemical properties and land-use types was not obvious based on the abovementioned analysis of soil pH, SOC, total nutrients, and available nutrients of different land-use types. Based on the relational analysis principle in gray system theory, gray relational analysis was applied to quantitatively evaluate the soil quality of different land-use types. The best effect can be obtained when the series with a high correlation degree is closest to the reference series [25]. In this study, the effects of different land-use types on soil were analyzed based on the chemical properties of soil. Using the weighted gray relational analysis, the maximum value of each index was selected as the factor to be evaluated. The reference series was set as $X_0 = \{6.0000, 485.9198, 0.7811, 5.8901, 49.6022, 302.1519, 51.2346\}$. The TN, AN, TP, AP, TK, AK, and SOC of different land-use types were used as comparison factors to carry out dimensionless treatment (Table 2). The gray relational analysis method was used to calculate the correlation coefficient and weighted correlation degree of each land-use type (Table 3). The greater the correlation degree is, the closer the trend of the comparison series to the reference series will be, indicating a better soil quality under the land-use type [26].

As shown in Table 3, the order of correlation degree of various land-use types in the upper soil layer was pear orchard (0.7919) > paddy field (0.7486) > dryland (0.6832) > flue-cured tobacco field (0.6480), while the order of correlation degree of various land-use types in the lower soil layer was pear orchard (0.7127) > flue-cured tobacco field (0.6818) > dryland (0.6634) > paddy field (0.6335). The correlation degree of pear orchard was the largest, indicating that the soil quality of pear orchard was the best among the land-use types that are affected by human activities, correlation degree of various land-use types in the soil surface layer was dolomite shrubland (0.9022) > forest (0.8138) > grass slope (0.7928) > pear orchard (0.7919) > limestone shrubland (0.7539) > paddy field (0.7486) > dryland (0.6832) > flue-cured tobacco field (0.6480). Considering only the surface layer of soil, dolomite shrubland had the highest correlation degree, followed by forest and grass slope, indicating that the soil quality of dolomite shrubland was the best, while the soil quality of flue-cured tobacco field was the worst.

4. Discussion

4.1. Changes in Soil Chemical Properties with Lithology. Soil chemical properties are affected by many natural factors, such as temperature, precipitation, land cover, and lithology, of which lithology is the important one [27]. As shown in Figure 5, SOC, TN, AN, and AK contents, as well as the soil pH of dolomite shrubland, were higher than those of limestone shrubland. The TK, TP, and AP contents in shrubland developed in limestone were higher than those in dolomite shrubland. This might be because the limestone shrubland in this research area was relatively moist, so the SOC, TN, AN, and AK were highly leached, resulting in a high soil acidity. The microbial species were limited by the acidic soil, thereby slowing down the decomposition of organic matter [28]. Thus, the nutrient contents of nutrients

in limestone shrubland were lower than those of dolomite shrubland and grass slope. However, the potassium and phosphorous elements of soil are mainly derived from the weathering of rocks [29]. The weathering rate of limestone is greater than that of dolomite, so the content of potassium and phosphorous in limestone soil is relatively high. Soil chemical properties were largely controlled by soil moisture [30], and the limestone soil in the research area was moist. In addition, the available nutrients have characteristics of easy solubility and sensitivity [31], so they are easy to be leached. The mobility of phosphorus in the soil is small [29]; thus, the TK, TP, and AP contents in shrubland developed in limestone were higher than those in dolomite shrubland, whereas AK showed the opposite trend. Wang et al. found that the SOC and TN were higher in dolomite compared with limestone, which was consistent with our results [32]. However, Li et al. reported that the carbon and nitrogen content of limestone-developed soil was significantly higher than that of dolomite-developed soil [33]. This difference may be due to differences in samples and study areas. Overall, soil chemical properties dynamics along with underlying lithologies indicate that lithology plays an important role in soil chemical properties in the karst area.

4.2. Changes of Soil Chemical Properties with Soil Layer.

Table 4 shows that there was no significant difference in pH and TK content of all land-use types between the different soil layers. There was also no significant difference between the different soil layers in the TN and AN contents in dryland as well as the AN content in flue-cured tobacco field. The coefficients of variation for these were all less than 10%. The coefficients of variation of the TN and SOC contents in the paddy field, the AK and SOC contents in flue-cured tobacco field, and the AP content in pear orchard were more than 50%, showing moderate variations. The coefficients of variation of other nutrients between the upper and lower soil layers were between 10% and 50%, showing strong variations. In general, the variations in dryland and pear orchard were relatively small, while the variations in paddy field and flue-cured tobacco field were large, showing clear differences between the upper and lower layers, indicating that they were greatly affected by human activities. The dryland in the research area was ploughed recently without planting crops, and the surface layer was not fertilized, while the roots of the pear trees were developed and there were weeds on the surface. As a result, human and natural biological activities had similar effects on soil nutrients in the upper and lower soil layers. There was only a small difference in soil nutrients between the upper and lower layers for these two types of land.

The contents of nutrients except potassium in the upper layer of soil were higher than those in the lower layer. Humification led to high organic matter content with the presence of litter on the soil surface layer, and the decomposition of organic matter released nitrogen and phosphorus, which resulted in a high surface nitrogen and phosphorus contents [26]. In addition, fertilization had a strong effect on soil properties [34], resulting in higher soil

TABLE 2: Nondimensionalized results of soil nutrient contents under different land-use types.

Land-use type	TN	AN	TP	AP	TK	AK	SOC
Upper paddy field	3.8154	0.6789	0.5137	2.1727	0.3173	0.6744	0.3569
Lower paddy field	0.8879	0.4069	0.3299	1.5589	0.3109	0.9948	6.4537
Upper dryland	1.4020	0.6252	0.4298	4.7103	0.2287	1.9059	9.2723
Lower dryland	1.2614	0.5943	0.3311	3.6114	0.2114	1.6518	7.3138
Forest	5.1484	2.7511	0.3416	2.8487	0.1564	1.6181	0.5123
Grass slope	4.0944	2.7810	0.7811	2.0813	0.1859	1.3951	0.4066
Dolomite shrubland	6.0000	4.8592	0.1302	1.7793	0.2438	3.0215	0.4395
Limestone shrubland	3.0493	1.0312	0.3856	2.4116	0.4960	1.2561	0.3239
Upper flue-cured tobacco field	1.3217	0.2625	0.4768	2.6370	0.3289	1.4135	8.2588
Lower flue-cured tobacco field	0.8034	0.2995	0.3853	4.1859	0.3377	0.6396	3.7416
Upper pear orchard	1.5489	0.8008	0.5542	5.8901	0.3513	1.0493	0.1306
Lower pear orchard	1.3396	0.5419	0.3921	2.4559	0.3281	0.6045	0.1010

TABLE 3: Gray correlation coefficients and correlation degrees of soil nutrient contents under different land-use types.

Land-use type	TN	AN	TP	AP	TK	AK	SOC	Gray relational degree
Upper paddy field	0.6672	0.5117	0.9425	0.5409	0.9608	0.6511	0.9657	0.7486
Lower paddy field	0.4614	0.4959	0.9066	0.5028	0.9594	0.6837	0.4244	0.6335
Upper dryland	0.4879	0.5085	0.9258	0.7878	0.9425	0.7970	0.3333	0.6832
Lower dryland	0.4803	0.5067	0.9068	0.6578	0.9390	0.7618	0.3917	0.6634
Forest	0.8372	0.6751	0.9088	0.5902	0.9280	0.7573	1.0000	0.8138
Grass slope	0.6968	0.6782	1.0000	0.5349	0.9339	0.7292	0.9764	0.7928
Dolomite shrubland	1.0000	1.0000	0.8706	0.5159	0.9456	1.0000	0.9836	0.9022
Limestone shrubland	0.5975	0.5336	0.9172	0.5574	1.0000	0.7127	0.9588	0.7539
Upper flue-cured tobacco field	0.4835	0.4879	0.9350	0.5738	0.9632	0.7315	0.3612	0.6480
Lower flue-cured tobacco field	0.4574	0.4899	0.9171	0.7199	0.9651	0.6477	0.5756	0.6818
Upper pear orchard	0.4960	0.5191	0.9508	1.0000	0.9680	0.6895	0.9198	0.7919
Lower pear orchard	0.4845	0.5036	0.9184	0.5605	0.9631	0.6444	0.9142	0.7127

TABLE 4: Nutrient coefficient of variations of soil in upper and lower layers of different land-use types (100%).

Land-use type	pH	TN	AN	TP	AP	TK	AK	SOC
Paddy land	1.3063	88.0252	35.4247	30.8045	23.2630	1.4408	27.1489	98.1107
Dryland	0.7443	7.4629	3.5785	18.3463	18.6740	5.5550	10.1032	16.6993
Flue-cured tobacco field	1.9207	34.4907	9.2965	15.0026	32.1052	1.8664	53.3061	53.2346
Orchard	0.7697	10.2500	27.2679	24.2224	58.1915	4.8319	38.0324	18.0483

nutrient contents in the upper than in the lower layer. Potassium is mainly affected by the soil parent material and the amount of artificial fertilization. There was no clear difference in the potassium content in the upper and lower layers. To sum up, these results could be attributed to management practices and microtopographical variations as these are the dynamic properties of soil [35].

4.3. Soil Quality Status. Table 5 shows that the contents of most elements in this study were close to those of the karst valley area, higher than those of the karst dry and hot valley area and the national average, and lower than those of the various land-use types in the karst peak-cluster and depression area. This indicates that the contents of the soil elements in this research area were at a relatively high level. This difference in elements contents was mainly due to the differences in hydrothermal conditions in the research areas and the different levels of human disturbance. The area in this study has the humid climate of the mid-subtropical mountainous region. The superior temperature and

humidity conditions are highly conducive to the reproduction and growth of organisms; thus, the biological self-fertilization effect is strong.

Among all land-use types, the TN, AN, and AK contents were highest, while the TP and AP contents were lowest in the dolomite shrubland. The SOC content was the highest and the TK content was the lowest in the forest. The SOC, TN, and AN contents in the flue-cured tobacco field were the lowest. The TP content in grass slope, TK content in limestone shrubland, and AP content in pear orchard were the lowest. The SOC mainly depends on the release amount of litter [38, 39]. The forest and grass slope are rich in surface organisms, and there is a large amount of litter accumulation every year, so the SOC contents are high. Moreover, the weathering speed of limestone is fast, and the layer of litter in limestone shrubland is thick, which is beneficial to the accumulation of potassium, resulting in a high potassium content. However, the dolomite forest had the lowest potassium content due to the thin soil layer and serious soil erosion, which led to the transfer of soil potassium. The nitrogen contents of forest and grass slope were relatively

TABLE 5: Comparison of soil nutrient contents with other regions.

Region	TN (g/kg)	TP (g/kg)	TK (g/kg)	SOC (g/kg)	Reference
Karst plateau mountain area	0.80–6.00	0.13–0.78	15.64–49.60	3.74–51.23	This study
Karst dry and hot valley area	0.03–0.27	0.10–2.00	1.24–11.88	—	Tian et al. [36]
Karst peak-cluster and depression area	4.29–6.90	1.15–1.47	3.59–6.05	109.02–158.62	Liu et al. [11]
Karst valley area	0.71–3.64	0.27–1.30	9.72–22.27	7.2–63.7	Li et al. [9]
Entire China	1.12	0.67	—	12.83	Tian et al. [37]

large. This is because the TN content in the shrubland is related to the accumulation of litter. The nitrogen in the soil is absorbed by plants and then returned to the soil in the form of litter [40]. Grass slopes and various types of forest have a large amount of litter and animal remains to supplement the phosphorus in the soil. Because the ecological structure of the forest is relatively complex and the ecosystem function is relatively strong, there are large amounts of phosphorus absorption, leading to a low content of TP in the soil. The correlation degree of various land-use types decreased in the following order: dolomite shrubland > forest > grass slope > pear orchard > limestone shrubland > paddy field > dryland > flue-cured tobacco field. Soil nutrient contents mainly depend on the release amount of litter and artificial fertilization. Dolomite shrubland, forest, grass slope, limestone shrubland, and pear orchard have a large amount of litter on the surface, so the soil quality is relatively good. The ecosystem in the karst region is fragile with a shallow soil layer. In paddy field, dryland, and flue-cured tobacco field, the soil quality was relatively poor under the disturbance of human activities such as land-use change, tillage, and fertilization. Among the four types of land-use that are strongly affected by human activities (paddy field, dryland, flue-cured tobacco field, and pear orchard), the soil in the pear orchard had the best soil quality under appropriate agricultural management. Jiang et al. also reported that when cultivated land was transformed into orchard land, organic matter, total N, total P, and total K increased significantly [41]. Therefore, reducing the disturbance of human activities is of great importance for the improvement of soil quality. In the process of artificial farming, soil productivity can be improved through reasonable agricultural management.

5. Conclusions

This study summarizes the following points of the results: (1) The total potassium, total phosphorus, and available phosphorus contents of soil in limestone shrubland were higher than those in dolomite shrubland, and the contents of other analyzed soil indexes are all higher in dolomite than in limestone. (2) Among paddy field, dryland, flue-cured tobacco field, and pear orchard, the nutrient contents (except potassium in the upper soil layer) were higher than those in the lower layer. (3) The gray relational analysis shows that soil quality decreased in the following order: dolomite shrubland > forest > grass slope > pear orchard > limestone shrubland > paddy field > dryland > flue-cured tobacco field.

In the present study, dolomite and limestone soil under different land-use types in the buffer zone of Shibing Karst

World Natural Heritage Property was selected as the present research object. We kept the climate and altitude of sample collection sites consistent to the greatest extent possible. However, the number of land-use types in the study area is limited, as there are only five land-use types for dolomite and three land-use types for limestone. Therefore, the land use types studied here under the two lithology conditions did not completely correspond. For this reason, the impact of lithology and land use types on soil chemical properties needs to be further studied by selecting natural study areas or performing simulation experiments in runoff plots under the same climatic conditions, at the same altitude, and with the same land use types.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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