Responses of soil physical and chemical properties to karst rocky desertification evolution in typical karst valley area

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Abstract. In order to reveal the differences of soil physical and chemical properties and their response mechanism to the evolution of KRD. The characteristics of soil physical and chemical properties of different grades of KRD were studied by field sampling method to research different types of KRD in the typical karst valley of southern China. Instead of using space of time, to explore the response and the mechanisms of the soil physical and chemical properties at the different evolution process. The results showed that: (1) There were significant differences in organic matter, pH, total nitrogen, total phosphorus, total potassium, sediment concentration, clay content and AWHC in different levels of KRD environment. However, these indicators are not with increasing desertification degree has been degraded, but improved after a first degradation trends; (2) The correlation analysis showed that soil organic matter, acid, alkali, total nitrogen, total phosphorus, total potassium and clay contents were significantly correlated with other physical and chemical factors. They are the key factors of soil physical and chemical properties, play a key role in improving soil physical and chemical properties and promoting nutrient cycling; (3) The principal component analysis showed that the cumulative contribution rate of organic matter, pH, total nitrogen, total phosphorus, total potassium and sediment concentration was 80.26%, which was the key index to evaluate rocky desertification degree based on soil physical and chemical properties. The results have important theoretical and practical significance for the protection and restoration of rocky desertification ecosystem in southwest China.
1. Introduction
China southern karst represents the world's most typical tropical-subtropical karst area [1], the area of the Karst Rocky Desertification(KRD) is widely distributed in this region, which seriously affects the living environment and living standards of the local people, leading to a series of social problems [2,3]. Rocky desertification can not only cause changes in surface morphology and vegetation, its essence is to make the soil material composition, physical and chemical properties and production performance changes [4], and this change due to the length of time and rocky desertification vary.

In recent years, some scholars have studied the soil physical and chemical properties of karst area. The main effect of soil, rocky desertification process and vegetation degradation effect on soil organic matter and soil organic carbon density and relations and so on, which provides an important scientific basis and theoretical support for the rocky desertification in karst area project management. However, the lack of further study on the soil physical and chemical properties of karst ecosystem and its temporal and spatial diversity and its response to rocky desertification are still less [5].

Therefore, this paper was based on the different grades of KRD soil in the typical karst valley area of southern China. The physical and chemical properties of soils in different grades of KRD were studied by field sampling method. The spatial substitution time method was used to investigate the response and mechanism of soil physical and chemical properties during KRD succession, which aims to provide theoretical support for the conservation and restoration of karst ecosystem in southwest China.

2. Study area
Yinjiang county is located in Tongren, Guizhou Province, China, the northeast Guizhou plateau, Yinjiang rivers of wujiang river water system in the Yangtze river basin watershed areas(Fig1). The geographical position of the study area is 108°17' to 108°48'N, 26° 35' to 28°28'E, and the land areas is 196900 hm$^2$. The soil erosion is mainly mild. The types of KRD are relatively complete, ranging from NKRD to ESKRD, among which mild and moderate KRD are dominant. The soil mainly yellow soil soil, mountain shrub meadow soil, Large mud, purple mud field, tidal sand mud and other soil species.

![Figure 1. The location of study area](image)
(Note: NKRD: No KRD; PKRD: Potential KRD; LKRD: Light KRD; MKRD: Moderate KRD; SKRD: Severe KRD; ESKRD: Extremely Severe KRD; NK: Non-karst)

2.1. Main methods

2.1.1. Interpretation of KRD, Firstly, non-karst is removed in the study area by lithology. Secondly, the land use map is the karst area of the town, where water and KRD cannot be deducted. Thirdly, the decision tree classification based on the CART decision tree classification method and the reference KRD grading index system (Table 1) are used to classify the KRD information.

| Classification and code of KRD type | Percentage of rock (%) | Distribution character of the exposed rock | Color of the RS image |
|-------------------------------------|------------------------|--------------------------------------------|-----------------------|
| No KRD(NKRD)                        | <20                    | Star                                       | Scarlet               |
| Potential KRD(PKRD)                 | 20~30                  | Star, Line                                 | Shocking pink         |
| Light KRD(LKRD)                     | 31~50                  | Line                                       | Pink                  |
| Moderate KRD(MKRD)                  | 51~70                  | Line, Patch                               | Green in red          |
| Severe KRD(SKRD)                    | 71~90                  | Patch, Line                               | Gray in red           |
| Extremely Severe KRD(ESKRD)         | >90                    | Patch                                     | White, gray           |
| Non-karst(NK)                       |                        | Non-karst areas do not involve rocky desertification |

2.1.2. Methods for Determination of Soil Physical and Chemical Properties, Quadrat Setting and Sampling Method

Combined with the distribution of vegetation and soil in the study area, six typical stages of KRD succession were selected as the research object. For the six study subjects, the soils in the KRD area were shallow, so only 0 ~ 15cm surface soil was taken as the research object. In each way to collect 3-5 mixed soil samples, with a quarter of about 1kg soil samples back to the laboratory.

Determination of Soil Physical Properties

On the basis of "soil physical and chemical analysis and profile description" in the requirements of the soil samples were air dried, remove impurities in animal and plant residues and leaves, mixed evenly, with agate grinding crushing and 100 mesh nylon sieves, determination of the physical and chemical properties of soil used for loading in plastic bags. Soil bulk density, soil available water content, field water holding capacity measured by ring knife method; sediment content, clay content using drying weighing method.

Determination of Soil Chemical Properties

pH value with 2.5: 1 soil and water ratio, measured by potentiometer method, determination of organic matter by potassium dichromate oxidation method, determination of total nitrogen with selenium powder-copper sulfate-sulfuric acid digestion method, determination of total phosphorus with perchloric acid-concentrated sulfuric acid-molybdenum antimony, total potassium with hydrofluoric acid - perchloric acid digestion, flame photometric determination.

Data Processing and Analysis

Using Arcgis software for data processing and mapping, analysis of soil physical and chemical properties of the correlation analysis and based on the KRD level of the principal component analysis is the use of software SPSS 20, correlation analysis using Analyze/Correlate process on the physical and chemical properties of Pearson correlation analysis, statistical significance level of $\alpha = 0.05$. 


3. Results and analysis
This study soil properties selected factor distribution of the region shown in Figure 3:

Figure 3. Spatial distribution of soil physical and chemical properties in the study area
3.1. Physical and Chemical Properties of Different Types of KRD Environment

The physical and chemical properties of soils under different KRD conditions were obtained by superimposing the different levels of KRD and soil physical and chemical properties (Table 2).

Table 2. different levels of rocky desertification environment soil physical and chemical properties

| KRD    | OM (%) | pH   | TN (%) | TP (%) | TK (%) | SAND (%) | CLAY (%) | AWHC   |
|--------|--------|------|--------|--------|--------|----------|----------|--------|
| NKRD   | 5.82   | 2.32 | 0.14   | 0.05   | 1.55   | 0.27     | 0.27     | 149.74 |
| PKRD   | 3.51   | 2.48 | 0.14   | 0.05   | 1.54   | 0.27     | 0.28     | 149.73 |
| LKRD   | 3.62   | 7.63 | 0.14   | 0.05   | 1.51   | 0.27     | 0.27     | 147.58 |
| MKRD   | 3.93   | 7.42 | 0.16   | 0.04   | 1.32   | 0.30     | 0.24     | 146.32 |
| SKRD   | 3.66   | 2.70 | 0.14   | 0.05   | 1.50   | 0.28     | 0.24     | 145.63 |
| ESKRD  | 3.43   | 3.03 | 0.16   | 0.04   | 1.35   | 0.29     | 0.23     | 141.98 |

(1) Soil organic matter: The soil organic matter in NKRD environment was 5.82%, and the soil organic matter was 3.51% in the PKRD environment, the LKRD environment of soil organic matter is 3.62%, MKRD environment of soil organic matter was 3.93%, the SKRD environment of soil organic matter was 3.66%, and the ESKRD environment of soil organic matter was 3.43%.

(2) PH: The soil pH was 2.32 in the NKRD environment, the PKRD environment soil pH value is 2.48, LKRD environment soil pH value is 7.63, and the MKRD environment soil pH value is 7.42, the SKRD environment of soil pH value is 2.70, the soil pH of ESKRD environment is 3.03. Soil pH values showed that the soil pH in the NKRD environment was significantly lower than that of potential, mild, moderate and mild KRD.

(3) Total nitrogen: The total nitrogen of soils in NKRD, PKRD, LKRD and SKRD environment were 0.14%, and the soil total nitrogen was 0.16% in MKRD and ESKRD environment. The results showed that there was no significant difference in soil total nitrogen under different desertification conditions, which indicated that the KRD environment was affected by source rock.

(4) Total phosphorus: The NKRD, PKRD, LKRD and SKRD environment of soil total phosphorus were 0.05%, MKRD and ESKRD environment soil total phosphorus were 0.04%. There was no significant difference in soil total phosphorus under different desertification environments, but the change trend of total phosphorus showed a high consistency with the change of total nitrogen.

(5) Total K: The soil total K of NKRD, PKRD, LKRD and SKRD environment is about 1.5%, the MKRD and ESKRD environment soil total potassium is about 1.3%. The results showed that there were differences in total K in soils with different grades of KRD, and NKRD was significantly higher than that of LKRD, MKRD and SKRD.

(6) Sediment concentration: The value of soil sand content in MKRD is 0.30%, which is higher than that in other KRD, while the soil sand content in other grades of KRD is not much different, which is about 0.28%, which indicates that the soil has the best water permeability during MKRD, but also has the characteristics of poor water retention and fertilizer performance.

(7) clay content: the lowest clay content is moderate KRD, the severe of rocky desertification, extreme KRD, respectively 0.24%, 0.23%, high clay content is no KRD, potential stone Desertification and mild KRD, respectively 0.27%, 0.28% and 0.27%, indicating that the higher the KRD content of the lower clay content, that is, the weaker ability to maintain water and fertilizer.

(8) AWHC: With the increase of KRD level, the effective water content in the field is getting smaller and smaller, and the effective water content of the soil to extremely severe KRD land is only 141.98.

3.2. The correlation of soil physical and chemical properties in KRD environment

There are significant correlations between organic matter and nitrogen in soil chemical properties and most other physical and chemical factors in soil. There was a significant positive correlation between organic matter and pH and total nitrogen, and negatively correlated with total phosphorus and total...
potassium. There was a significant negative correlation between pH and total nitrogen and sediment concentration, and negatively correlated with total phosphorus and total potassium. There was a significant negative correlation between total nitrogen and total phosphorus, total potassium and clay content. There was a significant positive correlation between total phosphorus and total potassium and clay content. There was a significant positive correlation between total potassium and clay content.

Table 3. Correlation of soil physical and chemical properties in rocky desertification environment

|       | OM    | pH    | TN    | TP    | TK    | SAND  | CLAY  | AWHC  |
|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| OM    | 1.000 |       |       |       |       |       |       |       |
| pH    | 0.953**| 1.000 |       |       |       |       |       |       |
| TN    | 0.979**| 0.915*| 1.000 |       |       |       |       |       |
| TP    | -0.979**| -0.915*| -1.000**| 1.000 |       |       |       |       |
| TK    | -0.995**| -0.965**| -0.978**| 0.978**| 1.000 |       |       |       |
| SAND  | 0.884* | 0.958**| 0.853*| -0.853*| -0.884*| 1.000 |       |       |
| CLAY  | -0.951**| -0.925**| -0.974**| 0.974**| 0.971**| -0.831*| 1.000 |       |
| AWHC  | 0.093 | -0.106| 0.124 | -0.124| -0.112| -0.363| -0.176| 1.000 |

Table 4. Analysis of the main components of KRD based on soil physical and chemical properties

| Soil Physical and Chemical Properties | Principal component |
|---------------------------------------|---------------------|
|                                       | 1                   | 2                   |
| OM                                    | 0.981               | -0.144              |
| pH                                    | 0.984               | 0.076               |
| TN                                    | 0.969               | -0.198              |
| TP                                    | -0.969              | 0.198               |
| TK                                    | -0.985              | 0.158               |
| SAND                                  | 0.947               | 0.319               |
| CLAY                                  | -0.957              | 0.233               |
| AWHC                                  | -0.052              | -0.989              |
| Eigenvalue                            | 7.224               | 1.622               |
| Contribution rate (%)                 | 80.262              | 18.028              |
| Cumulative proportion (%)             | 80.262              | 98.289              |

Note: ** Significant correlation at 0.01 level (bilateral). * Significant correlation at 0.05 level (bilateral).

3.3. Analysis of Main Components of KRD Based on Soil Physical and Chemical Properties

The results show that the contribution rate of principal component 1 is 80.26%, the contribution rate of principal component 2 is 18.03%, and the cumulative contribution rate is 98.29%, which is based on the analysis of soil physical and chemical properties. It can be seen that the first two main components retain the eight-soil physical and chemical properties of the material to evaluate the KRD characteristics of the vast majority of information, so the selection of the two main components as a basis for evaluation of KRD evolution.

4. Discussion

4.1. Responses and Mechanisms of Soil Physical and Chemical Properties in the Process of KRD

For a long time, people have always believed that with the degree of KRD increased, the degree of soil degradation is also increased, and heavy soil degradation in severe KRD is the most serious. However, the results show that the KRD environment, whether physical or chemical [7,8,9], does not evolve
with the increase of KRD level, but is a process of improvement after first degradation. The reason for this should be related to the rocking effect of bare rock in KRD environment. This aggregation effect refers to the bare rock that brings the atmospheric subsidence nutrients and their karst products into the surrounding soil [10,11].

The response of soil physical and chemical properties and its mechanism in the process of KRD evolution can be summarized as follows: the loss of soil nutrients due to loss of soil and water loss due to the destruction of forest vegetation, and the decrease of organic matter input of vegetation litter. With the increasing degree of KRD, the agglomeration effect of bare rock is obvious, and the accumulation of nutrients and karst products in the atmosphere increases the input of soil nitrogen and organic matter, and with the deepening of KRD, the less the soil and water loss is weaker and the soil nutrient loss is weaker, and the response of soil physical and chemical properties and its mechanism performance are obviously improved under the strong bare rock aggregation effect and weak soil erosion.

**Figure 4.** Response and mechanism of soil physical and chemical properties during KRD evolution

### 4.2. Physical and Chemical Properties of KRD Soil and Rehabilitation of KRD Ecosystem

In recent years, KRD control has become an important part of social and economic development in China, we have invested a lot of manpower and material resources, but the effect is not ideal. One of the important reasons is that KRD control lack of in-depth study on KRD environment soil, which led to the relevant technical measures still remain at the level of experience, can not only be said to be science, it is even wrong. For example, it is that the (extremely) intensity KRD environment has been regarded as the focus of governance in a very long time. In fact, according to the research results, the evolution of soil physico chemical properties of KRD ecosystem is a process which degrae first and then improve with increasing degree of KRD, soil conditions of the intensity KRD and rockless desertification are significantly better than the other grades of KRD environment, mild and moderate KRD environmental soil conditions but the worst. so, the treatment of mild, moderate KRD is the key, relative to the (extremely) strength of rock desertification control difficulty and cost, less investment, governance will reduce the difficulty will be able to achieve a better overall KRD control.

### 5. Conclusion

(1) There were significant differences in organic matter, pH, total nitrogen, total phosphorus, total potassium, sediment concentration, clay content and AWHC in different levels of KRD environment. But these indicators are not with the degree of KRD has been degraded, but a trend of degrading first and improving later.
(2) Through the correlation analysis, it was found that the soil organic matter, acid and alkali, total nitrogen, total phosphorus, total potassium and clay content had obvious correlation with other soil physical and chemical factors; the key factor of soil physical and chemical properties play an important role in improving soil physical and chemical properties and promoting nutrient cycling.

(3) Through the principal component analysis, it was found that the weight coefficient of organic matter, pH, total nitrogen, total phosphorus, total potassium, sediment concentration and clay content was bigger, which was the key index to evaluate KRD degree based on soil physical and chemical properties.

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