Assessment of Forest Soil Fertility in Yunfu City based on Grey Correlation*

Zhang Zhongrui Qi Ye Ding Xiaogang Yang Haiyan Wei Dan
Zhang Geng Zhu Hangyong Chen Li
Guangdong Provincial Key Laboratory of Silviculture, Protection and Utilization / Guangdong Academy of Forestry, Guangzhou, Guangdong, 510520, China

Abstract Due to the spatial heterogeneity of forest soil, it is a difficult problem to evaluate the forest soil fertility on a large scale. This study conducted a grid survey of forest soil in Yunfu City, Guangdong Province, and used the the gray correlation system to evaluate forest soil fertility in each county. The results showed that the effect of using the gray correlation analysis to evaluate soil fertility in Yunfu city was ideal, and the fertilizer strength in each county was in order of Yunan, Yun'an, Yuncheng, Xinxing, and Luoding. The results can provide an appropriate scientific basis for forestry division within the county scale.

Key words grey correlation; forest soil; fertility; Yunfu City

The soil is a loose surface layer capable of producing plant harvests on the land surface (Zinke 1962). In the process of soil formation, it is constantly affected by various factors such as time and space, therefore, soil often has spatial heterogeneity (Pickett & Cadenasso 1995). In particular, the spatial heterogeneity of soil nutrients is often widely influenced by natural factors and human activities (Olmo et al. 2016). Guangdong Province is located at the southern end of mainland China, with good water and heat conditions, diverse topography and landforms, and a long history of forestry management, which caused the characteristics of large random variation and structural differentiation of forest soil nutrient space in Guangdong Province (Zeng et al. 2017; Gou et al. 2019). As a result, how to evaluate the forest soil fertility on a large scale, and to guide forestry production and management becomes a difficult problem (Kalu et al. 2015; Wu et al. 2017).

In the past, soil fertility assessment studies on cultivated land were not uncommon, and they used the correlation between soil properties to evaluate (Jiang et al. 2017; Baloch et al. 2017; Fernando et al. 2018). However, unlike forest soil, the cultivated soil has the characteristics of mainly affected by human activities, relatively flat topography, and with the purpose of fertilization.

At present, there are relatively little researches on fertility assessment of forest soil, especially the evaluation of forest soil fertility on a large scale (Blaser et al. 2017). How to make a simple, intuitive and effective fertility evaluationin on a large scale is necessary for the evaluation of the ranking of many factors in forest soil.

In this study, the forest soil in Yunfu city in western guangdong province was taken as the research object. Through the grid survey of forest soil properties in Yunfu city, and the grey correlation analysis of forest soil fertility indexes based on county area was conducted to solve the problem: 1) Whether the gray correlation analysis can carry out the forest soil fertility assessment on a large scale; 2) How to assess the status of forest soil fertility in all counties of Yunfu City, and whether it can provide a scientific basis for

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Author: Zhang Zhongrui (1987—), male, engineer, E-mail: Zhangzhongrui126@126.com.

the forest division of Yunfu City based on the grey correlation analysis of forest soil fertility.

Materials and methods

Research area

Yunfu City is located in the central and western parts of Guangdong province, south of the middle reaches of the Xijiang River, with excellent ecological environment, and the forest coverage rate reached 67.05%, under the jurisdiction of Yuncheng district, Yun'an district, Xinxing county, Yunan county, and Luoding city. Yunfu City is a subtropical monsoon climate, the average annual rainfall is about 1,980 mm, adequate rainfall and higher temperature in summer, more precipitation and high temperature in autumn, and the less rain and high temperature in winter, which is a warm winter (Chen et al. 2017).

Methods

Soil survey

From October to December 2015, the soil sampling survey was carried out by the grid method in Yunfu City, Guangdong Province. According to the spatial distribution characteristics and area of the soil and vegetation combination type, the soil sampling points were set according to the conditions of representativeness, repeatability, and feasibility of the sampling area. A total of 684 sampling points were set. The soil drilling method was used at each sampling point to determine the soil fertility index.

Analysis and test of fertility index

In this study, soil pH, organic content, total phosphorus content, total potassium content, total nitrogen content, available phosphorus, available potassium, and alkaline nitrogen were included in the evaluation of forest soil fertility.

The test methods are as follows: the pH value is measured by the potential method, the total phosphorus content is acid-soluble-molybdenum anti-colorimetric method, the total potassium content is determined by sodium hydroxide alkali fusion-flame photometry, the total nitrogen content is determined by the semi-micro Kelvin method, the effective phosphorus content is extracted by ammonium fluoride-hydrochloric acid-molybdenum antimony colorimetric method, the available potassium content is extracted by ammonium acetate-flame photometry, the alkali nitrogen content is determined by diffusion absorption.

Analysis methods

Standard data array

By using the optimal value of each soil index as the reference sequence, the measured values of different soil indices constitute the comparative series.

The standard data array is:

$$x_0(k)=\{x_0(1),\ x_0(2)\ \cdots\ x_0(n)\}$$

The comparison sequence is:

$$x_i(k)=\{x_i(1),\ x_i(2)\ \cdots\ x_i(n)\}$$

$k=1, 2, \cdots, n$,

n means the number of the determination of soil indexes (n=8), i=1, 2, $\cdots$, m, m means the number of areas(m=3).

The dimensionless of soil index

The measured value of each soil index is transformed into the evaluation value, the original measurement data is dimensionless treated, and the measured value is divided by the reference value, the obtained quotient is a dimensionless value before 0-1 to achieve the dimensional consistency.

Correlation coefficient

The following formulas is used to calculate the grey correlation coefficient of each reference factor $\varepsilon_i(k)$:

$$\varepsilon_i(k)=\frac{\min\limits_i\min\limits_k\left|x_0(k)-x_i(k)\right|+\rho\max\limits_i\max\limits_k\left|x_0(k)-x_i(k)\right|}{\left|x_0(k)-x_i(k)\right|+\rho\max\limits_i\max\limits_k\left|x_0(k)-x_i(k)\right|} \quad \text{..... (1)}$$

In the formula, $\varepsilon_i(k)$ is the correlation coefficient of x_0 and x_i in the k point, The $\left|x_0(k)-x_i(k)\right|$ is the absolute value of the array x_0 and x_i in the k point. The $\min\limits_i\min\limits_k\left|x_0(k)-x_i(k)\right|$ is the least absolute value of factor i in the k point, also

known as the secondary minimum deviation. The $\frac{\max}{i}\frac{\max}{k}\left|x_0(k)-x_i(k)\right|$ is the Secondary maximum differential. ρ as the recognition differential, the range of the value is 0-1, ρ equals to 0.5 in this study.

Finding the equivalence correlation degree γi of soil fertility of different forest stands according to $\varepsilon_i(k)$:

$$\gamma i=\frac{1}{n}\sum_{k=1}^{n}\varepsilon_i(k)\cdots\cdots(2)$$

In the formula, n is the total number of soil fertility index, n =8.

Results

Forest soil fertility index in different regions

Comparing 8 fertility indexes in different areas of Yunfu City, there was no significant difference in forest soil pH value, total potassium content and available phosphorus content in different areas (Figure 1). The soil organic content in Yunan county was significantly higher than that of the other four counties, Yuncheng and Yunan were significantly lower than the other 3 counties. The total phosphorus content in Yunan county was significantly higher than that in the remaining 4 counties. The soil total nitrogen content in Yunan county was significantly higher than that of the other four counties, Yuncheng and Yunan were significantly lower than the other three counties. The soil available potassium content in Yuncheng and Yunan was significantly higher than that in Luoding. The soil alkali nitrogen content in Yunan county was significantly higher than that of the other four counties, and Yuncheng was significantly lower than Xinxing county. It can be seen that there is strong spatial variability of forest soil fertility between the five counties of Yunfu City. Except for the soil fertility conditions in Yunan, the fertility status of other counties is relatively difficult to assess.

Calculate the correlation of soil fertility index in different areas of Yunfu City (Table 1), the correlation between forest soil fertility index is relatively poor. Among all 28 pairs, only organic content has a significant positive correlation with total nitrogen content, total phosphorus content, alkali nitrogen content, total phosphorus content and total nitrogen content, and alkali nitrogen content. There was a significant negative correlation between total potassium content and organic matter content and total nitrogen content. Therefore, it is still difficult to assess the fertility status of different areas of Yunfu City by relying on the correlation between fertility index.

Construction of grey correlation system for forest soil fertility

Through the analysis of the the gray correlation system, it is shown that soil pH, soil total nutrient, soil available nutrients and other factors have an indirect or direct impact on forest soil fertility. All soil attributes were normalized to their respective sizes to determine the reference sequence (Table 2), and then the correlation coefficients and correlation matrices were calculated (Table 2).

The correlation value of customs clearance can objectively and truly reflect the difference between soil fertility and the optimal indicator set in the region. The higher correlation degree indicates that the soil fertility in this area is closest to the ideal fertility condition. In this study, the grey correlation coefficient (Table 3) and the related sequence (Table 4) of forest soil fertility indicators in 5 counties (districts) of Yunfu City were calculated. Yunan (0.852)> Yun’an (0.548)> Yuncheng (0.410) > Xinxing (0.401)> Luoding (0.397), that is, in the counties and districts of Yunfu City, the forest soil fertility in Yunan county is the highest, followed by Yun’an, Yuncheng again. and the forest soil fertility of Xinxing and Luoding is relatively poor.

Conclusion

It is difficult to make large scale quantitative assessment of the overall fertility status of forest soil in different areas of Yunfu City. The gray soil correlation

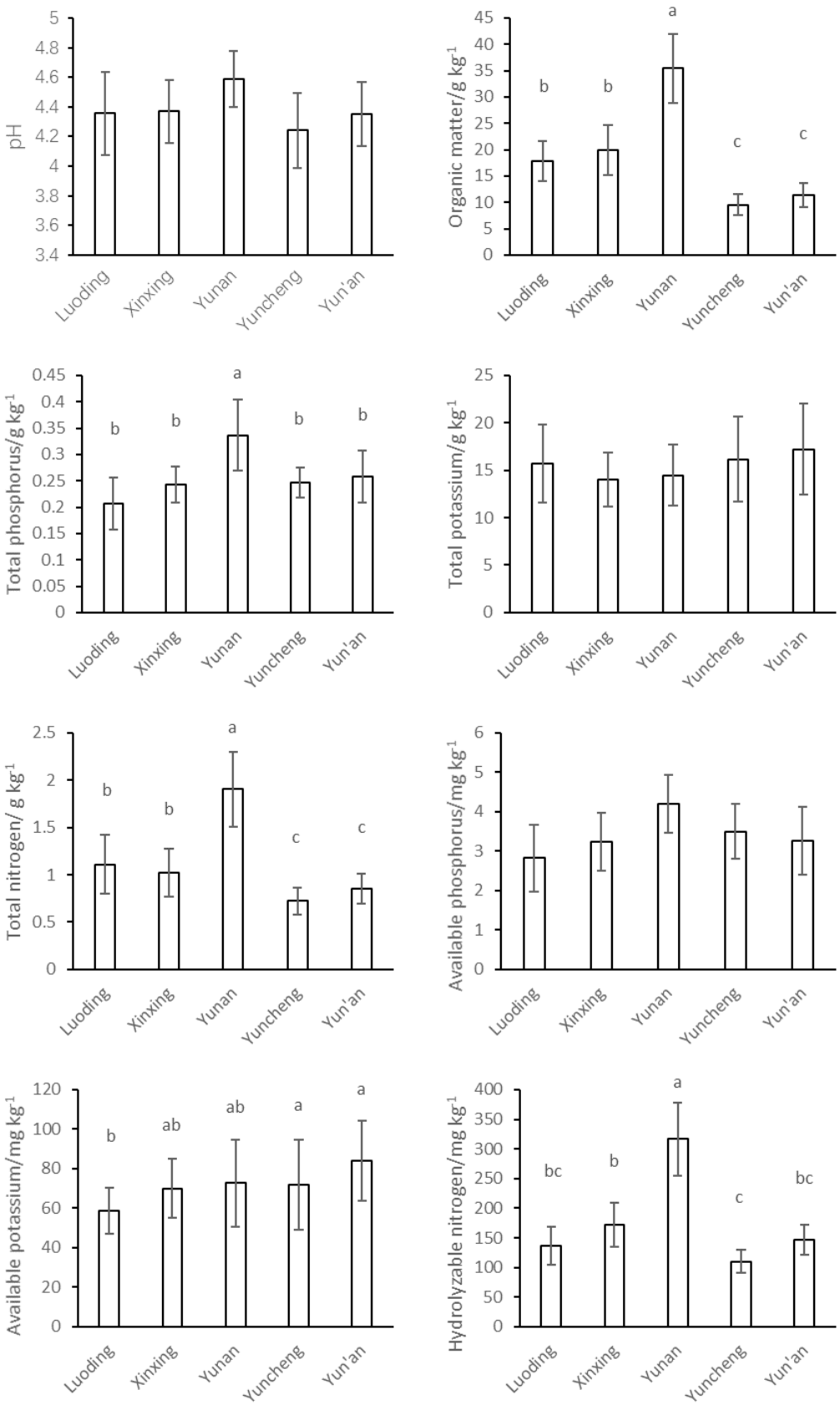

Figure 1 Soil fertility index in different areas of Yunfu City

system is used to formulate the ideal status of regional fertility in Yunfu City, and the relationship between each fertility index and its contribution to the overall fertility status is analyzed and determined, thus reflecting the similarity between the fertility status and the ideal situation in the local county (Lai et al. 2016). Through the analysis of the gray correlation system, the forest soil fertility in the five counties of Yunfu City can be sorted relatively intuitively, ranking: Yunan> Yun'an> Yuncheng> Xinxing> Luoding, which indicates that the gray correlation analysis is effective for the forest soil fertility assessment on a large scale.

Soil fertility is the result of multi-factor coupling, which is often associated with topography and vegetation factors (Elzobair et al. 2016). From the field

Table 1 The correlation of soil fertility index in different areas of Yunfu City

Index	pH	Organic matter	Total phosphorus	Total potassium	Total nitrogen	Available phosphorus	Available potassium
Organic matter	0.083						
Total phosphorus	0.194	0.489*					
Total potassium	–0.13	–0.278*	–0.043				
Total nitrogen	0.229	0.838*	0.512*	–0.244*			
Available phosphorus	–0.011	0.041	–0.026	–0.226	–0.050		
Available potassium	0.198	–0.225	–0.049	–0.026	–0.172	–0.010	
Available nitrogen	0.125	0.834*	0.618*	–0.190	0.827*	0.007	–0.107

Table 2 Reference sequence of forest soil fertility index in different areas of Yunfu City

Area	pH	Organic matter	Total phosphorus	Total potassium	Total nitrogen	Available phosphorus	Available potassium	Available nitrogen
Luoding	–0.220	–0.102	–1.204	0.153	–0.027	–1.265	–0.819	–0.545
Xinxing	–0.102	0.120	–0.358	–1.300	–0.247	–0.377	–1.008	–0.059
Yunan	1.827	1.812	1.831	–0.888	1.892	1.761	0.047	1.925
Yuncheng	–1.237	–1.013	–0.260	0.554	–0.964	0.213	–0.040	–0.909
Yun'an	–0.268	–0.816	–0.010	1.480	–0.654	–0.332	1.819	–0.412

Table 3 Grey correlation coefficient of forest soil fertility index in different areas of Yunfu City

Area	pH	Organic matter	Total phosphorus	Total potassium	Total nitrogen	Available phosphorus	Available potassium	Available nitrogen
Luoding	0.428	0.425	0.333	0.512	0.427	0.333	0.349	0.365
Xinxing	0.443	0.455	0.409	0.333	0.400	0.414	0.333	0.417
Yunan	1.000	1.000	1.000	0.370	1.000	1.000	0.444	1.000
Yuncheng	0.333	0.333	0.421	0.600	0.333	0.494	0.432	0.333
Yun'an	0.422	0.350	0.452	1.000	0.359	0.420	1.000	0.377

Table 4 Grey correlation coefficient of forest soil fertility index in different areas of Yunfu City

	Luoding	Xinxing	Yunan	Yuncheng	Yun'an
Correlation	0.397	0.401	0.852	0.410	0.548

investigation situation, Yunan County of Yunfu City is adjacent to the Xijiang River and has many low-lying areas. It has good ecological conditions and rich vegetation. The grid survey has a large proportion of the natural forest and the mixed forests dominated by zonal vegetation. Correspondingly, the soil conditions are relatively good. In Xinxing, Luoding and other areas, forest management should pay attention to local conditions and planting according to the environment. The nutrient of forest soil should be managed scientifically, Appropriate trees, scientific management of forest soil nutrients, and ensure a virtuous circle of nutrients in forest ecosystems to effectively protect forest soil resources.

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