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Comparative Analysis on Soil Basic Properties Between Southern and Northern Slopes in Funiu Mountain, China

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Abstract: The spatial variation of soil physical and chemical properties in Funiu Mountain was studied to provide references for identifying soil spatial variation mechanism in bordering land of China warm temperate zone and northern subtropical region. Using vertical gradient sampling and traditional statistics method, the soil samples at the altitude from 1640 m to 1870 m were collected to compare physical and chemical properties between south and north slopes of the Funiu Mountain. The results showed that soil pH, soil organic matter and soil total nitrogen were remarkably correlated with altitude change, but soil electrical conductivity, soil available nitrogen, available phosphors, available potassium, and total potassium were not related to altitude. With the increase of altitude, soil pH and total nitrogen increased, but soil organic matter decreased. Compared with the soil properties of northern slope in Funiu Mountain, soil acidity, electrical conductivity, and available nitrogen were higher in southern slope. Especially, the soil available nitrogen was much higher than the mean value observed in northern slope samples. The contents of soil organic matter, available phosphorus, available potassium, total nitrogen, and total potassium showed no striking difference on between southern and northern slopes. In conclusion, both altitude and slope direction significantly influenced spatial variation of soil properties in Funiu Mountain. It added to the boundary effect of Qinling Mountains, and revealed the interaction mechanism of the environmental elements such as land-climate-soil-ecosystem in Funiu Mountain.

Keywords: Altitude, comparison, soil properties, spatial variation, Funiu Moutain.

1. INTRODUCTION

Soil properties are the key ecological factors to control plant growth or fruit bearing. The research on the heterogeneity of soil basic properties at different spatial scales is beneficial to comprehend its formations and development processes. More importantly, it has major significance to understand relevant relationships between soil, biology, climate, topography, and vegetation, and some ecological processes, such as land use change, soil degeneration, and *et al*. [1].

As the eastward extension of Qinling Mountains, Funiu Mountain has the representative vertical distribution of physical geography in transitional region between the warm temperate zone and north subtropical zone in China [2]. So this research on spatial variation of its soil basic properties has the vital significance to explore spatial differentiation mechanism of mountainous soil and guide its land use in this transition region. The existed similar researches almost focused on the small scale because both collection and determination of soil samples need to consume too much time, labour and money [3]. And existed landscape scale researches mainly concentrated on some specific land use patterns, such as wetland, forestland, grassland, farmland. Their results largely showed that soil physicochemical properties had strong spatial

physicochemical properties had strong spatial heterogeneity in large or small scale [4-7]. In China, Xiang *et al*. had considered that there was higher active organic carbon content in higher altitude regions of west Sichuan of China than one in lower altitude regions [8]. Zhang *et al*. had thought that elevation in Huoditang of Qinling Mountains had a significant correlation with Ph, organic matter, total nitrogen, and available phosphorus [9]. Wang and Che had believed that soil organic matter content declined gradually with depth, and rose gradually with elevation [10]. And soil bulk density had obvious increasing trend on the profile level while decreasing trend on the elevation gradient. With regard to comparison between southern and northern slopes in Funiu Mountain, the existed researches almost focused on climate and vegetation [11, 12], even resources exploitation and utilization of plants or animals or tourism [13]. But till now, there is little research on soil properties. By the traditional statistical method, this research does it so as to provide the theoretical basis of mountainous environment spatial variation mechanism in borderland between warm temperate zone and north subtropical zone in China.

2. MATERIALS AND METHODOLOGY

2.1. Study Area

Funiu Mountain lies in between 110°30′-113°05′E and 33°10′-34°10′N, with a total area of 10 000 km2, and with relative highness difference from 1000 m to 1700 m in landform. It runs NWW to SEE stretching about 300 kilo-
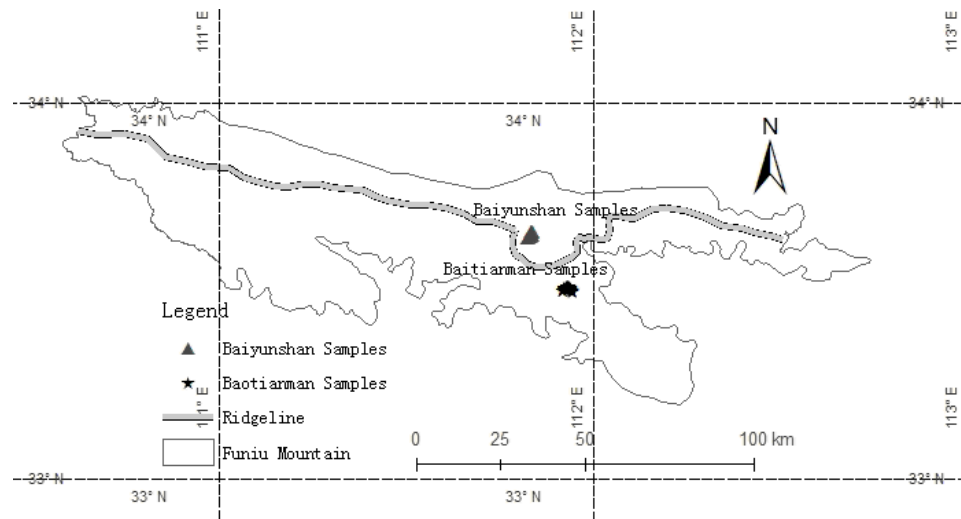
Fig. (1). Locations of Funiu Mountain and soil samplings.

meters from east to west and approximately 40-70 kilometers from south to north (Fig. (**1**)). Its striking characteristic is transition trait of climate and landform in south-north direction [14]. So all sampling plots of this research are located on both southern and northern slopes so as to comparative study. On southern slope, there is a national nature reserve named Baotianman, which was covered by the "Man and Biosphere Program" by UNESCO since 2001. It is the best-preserved natural comprehensive gene pool in the central region of China and one of the diversity regions in the world [15]. On northern slope, there is another national nature reserve named Funiushan, which is the water source of the Huaihe River and the drainage watershed of three river systems of the Yangtze River, the Yellow River and the Huaihe River [16], all famous for their huge runoff banks and vast watershed acreages.

2.2. Samples Collection

Soil samples collection were taken on from 1 to 9 of June in 2011. According to a rule named vertical gradient sampling method, setting up a plot with each 50 m up in this study, there are sixteen plots at the altitude from 1640 m to 1870 m, nine on southern slope and seven on northern slope. At each plot, a soil profile was dug until the bedrock was reached and the main topographic variables (altitude, aspect and slope) were recorded. Surface Depth (between the top and bottom parts of the horizon) ranged between 11 and 18 cm for surface horizons and between 22 and 51 cm for subsurface horizons. The samples were homogenized and a subsample for each core was taken for laboratory analyses.

2.3. Samples Processing and Laboratory Test

All samplings were air-dried at room temperature for 48 h and passed through a 2 mm sieve. Identifiable root material and stones were removed during sieving, using paper bags sealed for equipment analysis. Indoor physical and chemical analysis of soil samples was performed. Soil Ph was measured using a 1:2 soil: water ratio after equilibration for 30 min [17], and electrical conductivity radiometer for soil electrical conductivity and Tyuin's method for determination of soil organic matter [18]. Available

nitrogen, phosphorus and potassium were determined following extraction in 2 M KCl, and extracted using acidified NH4OAc-EDTA [19], and measured using ammonium acetate method, respectively. Total nitrogen were determined a dry combustion method. Since we know the value of available potassium, and non-exchangeable potassium was analyzed with the boiling nitric acid method, total potassium can be calculated by available potassium and non-exchangeable potassium. Total phosphorus is not thought as a general supply index in this research, since its conversion is rather slow in mountainous region.

2.4. Data Analysis

In this article, spatial variation of soil data was analyzed with geo-statistical technique. In the first place, soil basic properties were analyzed on southern slope or northern one. And then, parameters (minimum, maximum, mean, standard deviation, and coefficient of variation) for descriptive statistics were calculated, and compared in term-by-term between southern and northern slopes.

3. RESULTS

3.1. Soil basic Properties on Southern Slope

From Table **1** of soil chemical properties of southern slope, the variation coefficients of soil pH, organic matter and total potassium are small while ones of other indices are big, including soil conductivity, available nitrogen, available phosphorus, available potassium, total nitrogen, if being bounded by 15%. Total nitrogen, especially, was correlated positively with altitude while organic matter was correlated negatively with altitude. We may clearly understand it from Fig. (**2**) of results through single-variable analysis of statistical package for the social sciences (shorted for SPSS). And no significant correlation was found between the other soil indices and altitude.

From Table **2** of soil chemical properties of northern slope, we knew that the variation coefficients of soil Ph, organic matter, available nitrogen and total potassium were less than 15 percent while ones of other indices were more than 15 percent. Soil pH and total nitrogen were signifi-

Table 1.   Soil basic properties of southern slope in Funiu Mountain.

No.	Altitude (m)	pH	Electrical conductivity (Ms/cm)	Organic matter (g/kg)	Available nitrogen (mg/kg)	Available phosphorus (mg/kg)	Available potassium (mg/kg)	Total nitrogen (%)	Total potassium (%)
S1	1863	5.03	0.106	32.25	376.82	3.10	73.3	0.50	1.90
S2	1830	5.27	0.095	33.60	299.79	1.74	83.6	0.35	2.14
S3	1800	4.88	0.117	36.27	347.83	3.16	120.7	0.46	2.07
S4	1775	4.63	0.097	40.25	247.70	2.34	84.6	0.26	1.94
S5	1752	4.81	0.068	33.83	208.17	2.64	52.6	0.21	1.73
S6	1745	5.12	0.078	40.25	210.81	1.78	57.8	0.24	1.35
S7	1715	5.08	0.093	41.48	263.51	2.86	159.12	0.28	1.94
S8	1685	4.66	0.076	42.07	247.70	2.45	65.0	0.26	1.99
S9	1645	5.11	0.094	43.25	260.87	2.04	142.0	0.26	1.81
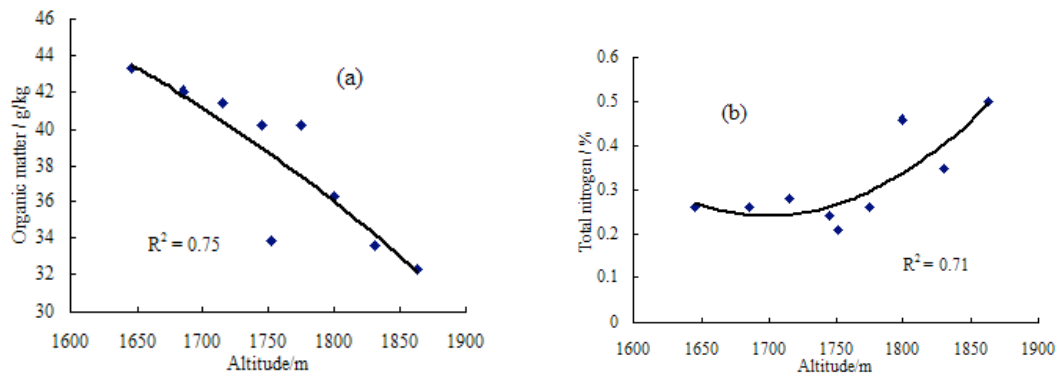
Fig. (2). Variation of soil organic matter (**a**) and total nitrogen (**b**) in different altitudes on southern slope.

Table 2.   Soil basic properties of northern slope in Funiu Mountain.

No.	Altitude (m)	pH	Electrical conductivity (Ms/cm)	Organic matter (g/kg)	Available nitrogen (mg/kg)	Available phosphorus (mg/kg)	Available potassium (mg/kg)	Total nitrogen (%)	Total potassium (%)
N1	1870	5.52	0.109	45.20	221.35	2.16	114.6	0.44	1.76
N2	1810	5.75	0.101	43.01	226.62	2.17	128.1	0.36	1.81
N3	1782	5.17	0.077	35.22	174.57	1.81	67.2	0.41	2.02
N4	1750	5.19	0.075	32.40	208.17	1.94	74.4	0.42	2.44
N5	1720	5.31	0.070	31.31	187.09	1.94	100.1	0.32	1.85
N6	1674	4.86	0.090	35.82	234.52	2.56	112.5	0.36	2.00
N7	1650	4.83	0.084	45.07	255.60	3.01	83.6	0.29	2.27

cantly positive with altitude, and the main results of single-variable analysis through SPSS in Fig. (**3**). Then there was no other indices correlated with altitude.

3.2. Comparison between two slopes

There are certain differences on soil chemical properties between southern and northern slopes from Table **3**, but the degrees were not the same and the variation trends were difference with the increasing of the plot heights. Soil acidity of sampling plots was stronger on southern slope than on northern slope, but both decreased with altitude on southern or northern slope. Soil electrical conductivity was higher on southern slope, and they were positive correlated with altitude, on northern slope or on southern slope. There
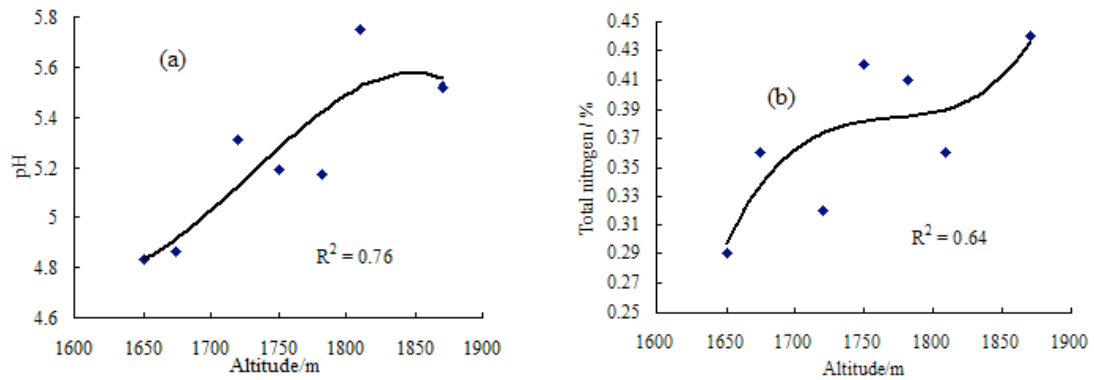
Fig. (3). Variation of soil pH (**a**) and total nitrogen (**b**) in different altitude on northern slope.

Table 3.   Soil basic properties comparison between southern and northern slopes in Funiu Mountain.

Basic properties	Min.		Max.		Mean		S D		C V /%	
	North	South	North	South	North	South	North	South	North	South
pH	4.83	4.63	5.75	5.27	5.23	4.95	0.332	0.221	6.35	4.46
Electrical conductivity (Ms/cm)	0.070	0.068	0.109	0.117	0.087	0.092	0.014	0.015	16.54	16.77
Organic matter (g/kg)	25.22	32.25	45.20	43.25	38.29	38.14	7.768	4.168	21.07	10.93
Available nitrogen (mg/kg)	174.57	208.17	255.6	376.82	215.42	273.69	27.880	57.75	12.94	21.10
Available phosphorus (mg/kg)	1.81	1.74	3.01	3.16	2.23	2.46	0.422	0.532	18.96	21.65
Available potassium (mg/kg)	67.2	52.60	128.1	159.12	97.21	93.19	22.750	38.311	23.40	41.11
Total nitrogen (%)	0.29	0.21	0.44	0.50	0.37	0.31	0.055	0.102	14.78	32.59
Total potassium (%)	1.76	1.35	2.44	2.14	2.02	1.87	0.252	0.232	12.45	12.39

Note: S D and C V means standard deviation and coefficient of variation, respectively.

is a significant difference of soil organic matter between northern and southern slopes. Namely, it was no striking change with altitude increasing on northern slope while it has obvious decreasing trend on southern slope. Bo be mentioned, there was no change trend of soil available nitrogen with altitude increasing on southern or northern slope. But the value of soil available nitrogen on southern slope was above 27 percent than ones on northern slope, averagely. On southern or northern slope, the soil total nitrogen was positive correlated with altitude, though the value of southern slope was slightly lower than ones on northern slope. Concerning other indices, such as available phosphorus, available potassium and total potassium, there was no significant difference on southern or northern slope, and was no clear correlation with altitude.

4. DISCUSSION

As survival carrier of plants, soil was influenced by specific parent material, climate, landform, forming process and humans activity, so its spatial heterogeneity was striking [20, 21]. Generally, the climate along altitude gradient presented more and more cold or damp within certain elevation, and hydrothermal and vegetation conditions turned to change [22]. Therefore, the spatial pattern and forming process of mountain soil had close relation-

ship with altitude. In this article, soil pH, organic matter and total nitrogen were all evidently affected by altitude on northern or southern slope plots from 1640 m to 1870 m of Funiu Mountain. This conclusion is similar to the results of Dang *et al*. on northern slope of Qinling Mountains and Wang *et al*. on southern slope of Gongga south mountain-Laguigangri Mountain [23, 24]. Concerning the comparison of soil properties between different slope plots, its acidity, conductivity and available nitrogen were significantly higher on southern slope than ones on northern slope, which showed slope had significantly effected on spatial heterogeneity of soil properties. It was both lower temperature and more coniferous trees on northern slope that may aggravate acid leaching process, which cause weak mineralization rate, then lower conductivity and weaker acidity of plots [25]. Because of lower temperature on northern slope, relatively slower rate decomposition of organic matter made significantly lower value of soil available nitrogen on northern slope of Funiu Mountain [26].

This study had showed that soil basic properties of mountain forest had a strong complexity in Funiu Mountain, resulted from many influencing factors, including altitude, slope, temperature, species composition, mineralization rates. Therefore, our expand research should be on the multidimensional positioning monitoring so as to grasp

spatial variation characteristics of soil basic properties, more scientifically and accurately.

CONCLUSION

With SPSS 13.0 package, this research has compared the soil basic properties between southern and northern slopes of the Funiu Mountain. Soil pH, organic matter, and total nitrogen presented regularly changed in spatial distribution along with altitude gradient, but the other not. With the ascent of the altitude, soil total nitrogen went up remarkably while both soil acidity and organic matter had a decreasing trend, on northern or southern slope. Compared with soil properties of plots on northern slope, soil acidity, electrical conductivity, and available nitrogen were higher on southern slope, but the other no great difference or similarly. It is both altitude and slope direction that are the important factors influenced spatial differentiation of soil basic properties in Funiu Mountain.

CONFLICT OF INTEREST

The author confirms that this article content has no conflict of interest.

ACKNOWLEDGEMENT

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