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ON THE DIVISION OF NORTH BOUNDARY OF SUBTROPICAL ZONE ACCORDING TO THE COMPOSITIONS AND PROPERTIES OF SOIL HUMUS

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ABSTRACT: In this paper predecessors' achievements about the division between subtropical zone and warm temperate zone on the south slope of Funiu Mountain are firstly summarized, and the cause why these viewpoints about the division are different also has been presented. Seven soil profiles at different heights above sea level are dug along the south slope of Funiu Mountain. Many compositions and properties of soil humus have been analyzed in laboratory. A comprehensive study has been made about the division according to the compositions and properties of soil humus with mathematical method. During the analysis process eight indexes have been used, such as altitude, organic carbon, humic acid (HA), fulvic acid (FA), the ratio of humic acid and fulvic acid (HA/FA), two extinction coefficients (E_4, E_6), and their ratio (E_4/E_6). The result indicates that the boundary is at about 1000 meters above sea level.
KEY WORDS: Funiu Mountain; north boundary of subtropical zone; soil humus

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1 INTRODUCTION

The boundary between subtropical zone and warm temperate zone, the north boundary of subtropical zone, is not only important in physical geography, but also attractive in agricultural production. So scientific division of the north boundary of subtropical zone has important theoretical and practical significance. This paper studies the boundary in west Henan mountainous areas on the basis of the author's on-the-spot investigation and laboratory works of soil analysis according to the compositions and properties of soil humus, which will supply more scientific theoretical basis for the division.

2 ARGUMENTS ABOUT THE NORTH BOUNDARY OF SUBTROPICAL ZONE IN WEST HENAN PROVINCE

With regard to the division of the north boundary of subtropical zone in west Henan mountainous areas, there are several different viewpoints in academic circles: LIU Shen-e, SHI Hua-min *et al.* advocate that the boundary is along the main ridge of Funiu Mountain (LIU, 1959; SHI, 1963); HOU Xue-yu, QIU Bao-jian and KUANG Sheng-shun, the north slope of it(HOU *et al.*, 1959; QIU, 1962; KUANG *et al.*, 1961); XIAO Ting-kui, ZHANG Guang-ye, ZHANG Jin-quan, LI Ke-huang, QUAN Shi-lin and the authors, the south slope of it(XIAO *et al.*, 1962; ZHANG *et al.*, 1965; ZHANG, 1981; LI, 1983; QUAN *et al.*, 1984; MA, 1999); however, different scholars, holding the south slope, adopt different heights and specific locations where the boundary passes: XIAO Ting-kui *et al.* hold that the north boundary of subtropical zone on the south slope of Funiu Mountain is in accordance with 1000m contour line(XIAO *et al.*, 1962); ZHANG Jin-quan, 800m contour line from the angle of geo-botany (ZHANG, 1981); LI Ke-huang, according to the types of thermal degree and properties of basic zone, the south foot of it, 2also pointing out the boundary spreading north to 33°35′N from the gullies of the Laoguan River and the White River, and south nearly to 33°10′N from the watershed of the two rivers(LI,

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1983); QUAN Shi-lin, $33°N \pm \Delta X(\Delta X = 15' - 30')$, on the basis of lots of data of heat and precipitation given by meteorological observatories, with fuzzy mathematical method(QUAN *et al.*, 1984). The author suggests that the north boundary of subtropical zone is at about 950m above sea level according to soil material migration and accumulation with cluster analysis method (MA, 1999).

In our opinion, there are two major reasons for the above different viewpoints. Firstly, the physical conditions of the north boundary of subtropical zone are unsteady and more complex than that of the central area. The roles of zonal factors are often enlarged, and people's understanding on the north boundary of subtropical zone are usually influenced by the dynamic variation of the water and thermal conditions caused by azonal factors. Besides, the gradual change of the physical conditions between subtropical zone and warm temperate zone brings some objective difficulties in analyzing the boundary. Secondly, the different purposes of division and special stresses on serving agriculture with different indexes lead to the different results of delimitation.

3 COLLECTION AND EXPERIMENTAL RESULT OF SOIL SAMPLES

According to the areal differentiation law, soil of the south slope of Funiu Mountain consists of yellow cinnamon soil, yellow-brown earth, brown forest soil, dark brown forest soil and meadow soil from foot to top. Thus, in theory the transitional belt from yellow-brown earth to brown forest soil is the north boundary of subtropical zone. In order to research the exact location of the boundary, we collected 7 typical soil profiles which are located in the south slope of Funiu Mountain in Xixia County, Henan Province according to the differences of altitude and conditions of soil formation. The physical conditions of all 7 profiles are listed in Table 1.

In laboratory, we analyzed the compositions of soil humus. The experimental results are shown in Table 2.

4 ANALYSIS AND DISCUSSION ON THE NORTH BOUNDARY OF SUBTROPICAL ZONE

From the viewpoints of climate and vegetation, the south slope of Funiu Mountain belongs to humid and semi-humid climate and its vegetative cover is mainly forest. Under the condition of the forest, the soil eluviation is much stronger, pH value shows from neutral to acid and the soil microorganism are mainly fungi, all of which stimulate the formation of FA. Therefore, in every soil profile, the soil humus mainly consists of FA and the value of HA/FA is smaller than 1. But because of the different conditions of soil formation at different heights of the slope, the values of organic carbon and HA/FA of the soil humus obviously indicate the law of the vertical differentiation.

From Table 2, it can be known that from the foot to the top except individual profiles both the content of organic carbon and the value of HA/FA have the trend towards gradual increase and the progressive increase rate becomes larger and larger over 1000m above sea level in the first layer of soil. As far as two profiles almost at the same height are concerned, if the content of organic carbon of one profile is higher, its value of HA/FA is comparatively lower. For instance, the content of organic carbon at S_1 is 0.70%, lower than that (1.91%) at S_2, while the value of HA/FA at S_1 is higher than that at S_2, respectively 0.18 and 0.12. The same phenomenon also appears not only between S_3 and S_4, but also S_6 and S_7, which is mainly caused by the different percentage of forest cover. The higher the percentage of forest cover is, the thinker the layer of withered branches and fallen leaves. Thus, the soil is rich in organic carbon with lower pH value. Under this condition, the humic acid mainly consists of FA with

Table 1 The physical conditions of all 7 soil profiles

Profile	Location	Height (m)	Vegetation type	Parent material
S_1	200m, north of Duiwa gully	550	Shrub and sparse forest	Xiashu Loess
S_2	Daliping, Sanlihao	675	Deciduous broad-leaved and coniferous mixed forest	Weathering residues of granite
S_3	100m, west of Dongping	900	Deciduous broad-leaved forest	Weathering residues of schist
S_4	Back mountain of Xidi village	1000	Deciduous broad-leaved and coniferous mixed forest	Weathering residues and slope sediments of granite
S_5	500m, south-west, of Jijiaojian peak	1500	Deciduous broad-leaved and coniferous mixed forest	Weathering slope sediments of granite
S_6	Sandaozhuang	2000	Bamboo forest	Weathering residues and slope sediments of granite
S_7	Jijiaojian peak	2212	Shrub	Weathering residues of granite

Table 2 The compositions of soil humus

Profile	Depth (cm)	Organic carbon (%)	HA (% of total C)	FA (% of total C)	Humin (% of total C)	HA/FA
S_1	0 – 15	0.70	4.29	24.29	71.42	0.18
	15 – 36	0.16	– –	– –	37.50	– –
	36 – 74	0.15	– –	– –	60.00	– –
S_2	2 – 10	1.91	4.19	34.03	61.78	0.12
	10 – 23	0.46	6.52	34.78	58.70	0.19
	23 – 45	0.34	– –	– –	94.12	– –
	> 45	0.19	– –	– –	36.84	– –
S_3	4 – 11	1.41	8.51	39.01	52.48	0.22
	11 – 33	0.39	10.26	61.54	28.20	0.17
	33 – 56	0.30	10.00	90.00	0.00	0.11
	> 56	0.17	– –	– –	41.18	– –
S_4	2 – 15	1.38	7.97	67.39	24.64	0.12
	15 – 47	0.63	6.35	52.38	41.27	0.12
	> 47	0.23	4.35	52.17	43.48	0.08
S_5	12 – 22	4.52	6.42	17.48	76.10	0.37
	22 – 34	1.92	5.18	34.20	60.62	0.15
	34 – 54	1.89	6.35	40.21	53.44	0.16
	54 – 65	1.49	10.07	44.30	45.63	0.23
S_6	0 – 20	10.28	11.87	20.91	67.22	0.57
	20 – 33	4.64	9.05	26.94	64.01	0.34
	33 – 58	3.02	11.26	32.45	56.29	0.35
S_7	0 – 20	7.25	10.90	18.35	70.75	0.59
	20 – 50	3.09	6.80	56.96	36.24	0.12
	50 – 70	1.96	10.71	64.80	24.29	0.17
	> 70	1.22	3.28	57.38	39.34	0.06

simple structure. Therefore, the value of HA/FA is comparatively low. Otherwise, the content of organic carbon is lower and the value of HA/FA is higher. At low mountainous and hilly areas (under 1000m above sea level), the percentage of forest cover changes greatly due to human activities. So the above-mentioned phenomenon appears more obvious at over 1000m above sea level. On the whole, both the content of organic carbon and the value of HA/FA increase gradually from foot to top.

In order to analyze the properties of soil humus, we measured the densitometric feature of the first layer of the soils, the results are listed in Table 3 and shown in Fig. 1.

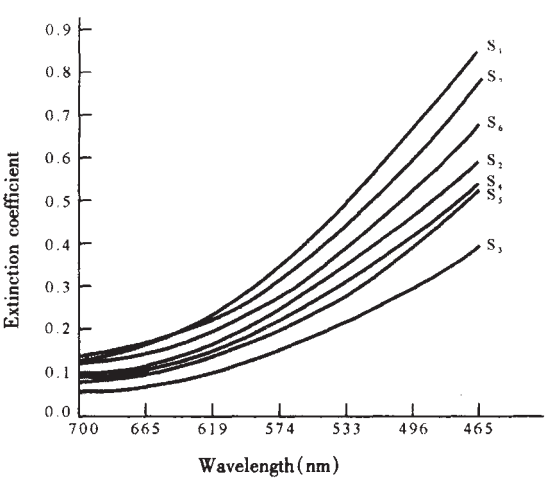

Fig. 1 The densitometric curve of humin acid of the first layer of the soils

From Table 3 and Fig. 1, it can be known that from S_1 to S_4 and from S_5 to S_7, the values of E_4, E_6 and E_4/E_6 all evidently present the law of vertical change: with the increase of height over 1000m above sea level, from S_5 to S_7, E_4/E_6 decreases from 5.36 to 4.92, while E_6 increases from 0.097 to 0.157 and E_4 from 0.520 to 0.773; the densitometric curves are arranged successively from below to above, in addition, its slope becomes greater and greater, which indicates that from S_5 to S_7, with the increase of height, the molecular weight of HA grows larger and larger; the content of carbon in aromatic nucleus increases little by little, while the content of carbon and hydroxy in non-aromatic chemical compound attached to side chain and the general acidity

Table 3 The densitometric feature of the first layer of the soils

Densitometric feature	S_1	S_2	S_3	S_4	S_5	S_6	S_7
E_4	0.847	0.618	0.397	0.532	0.532	0.676	0.773
E_6	0.157	0.110	0.067	0.101	0.097	0.135	0.157
E_4/E_6	5.40	5.62	5.93	5.27	5.36	5.01	4.92

decrease gradually; aromatic structural degree of HA becomes stronger and stronger under 1000m above sea level. From S_3 to S_1, except S_4, E_4/E_6 drops from 5.93 to 5.40, while E_6 rises from 0.067 to 0.157, and E_4 from 0.397 to 0.847. The position of the densitometric curve of S_1 is the highest and that of S_2, middle. This case makes it clear that from S_4 to S_1, aromatic structural degree of HA is also raised on a large scale.

This kind of vertical change of aromatic structural degree of HA is rare in middle and south subtropical zone and tropical mountainous areas which is the comprehensive reflection of special geographical and environmental conditions on the south slope of Funiu Mountain. With the decrease of height under 1000m above sea level, solar radiation gets stronger and stronger; the aridity is comparatively higher owing to less precipitation; the vegetative cover is inferior to that in the top because of human activities. So the soil humus decomposes quickly and the soil becomes enriched in aluminium. Such environmental conditions have advantage to the promotion of aromatic structural degree of HA, while are not favorable for the accumulation of organic carbon and the formation of HA. With the increase of height over 1000m above sea level, the precipitation firstly increases and then decreases (the height of the maximum precipitation is about 1300m) (YAN *et al.*, 1987), the temperature falls constantly, the percentage of vegetative cover is higher, the vegetation type shifts from deciduous broad-leaved and coniferous mixed forests into shrubs, the organic carbon decomposes slowly and aluminium-enrichment doesn't occur. This vertical change of the environmental conditions is favorable for the accumulation of soil humus, the formation of HA and the promotion of aromatic structural degree of HA.

We have carried out cluster analysis in order to analyze the vertical change of compositions and properties of soil humus and scientifically discover the boundary between north subtropical zone and warm temperate zone. We selected 8 indexes totally in the first layer of every profile, such as altitude, the content of organic carbon, HA, FA, HA/FA, E_4, E_6, E_4/E_6. With SPSS statistics software and cluster analysis of the furthest distance system, taking cosine distance as statistics, we have obtained the classification figure of soil (Fig. 2) according to the soil humus compositions and properties of the south slope of Funiu Mountain.

From Fig. 2, it can be seen that S_5, S_6, S_7 profiles can be classified as the same category indicating the similarity of the soil humus compositions and properties. They belong to the category of temperate zone soil, while S_1, S_2, S_3, S_4 profiles, another category, subtropical zone soil. However, Fig. 2 also shows that S4 is further away from S_1, S_2, S_3, and there are some differences between S_4 and S_1, S_2, S_3. Summarizing above analysis, taking predecessors' research results into consideration, we can get the conclusion that the north boundary of subtropical zone is close to S_4 profile and the height of it is about 1000m.

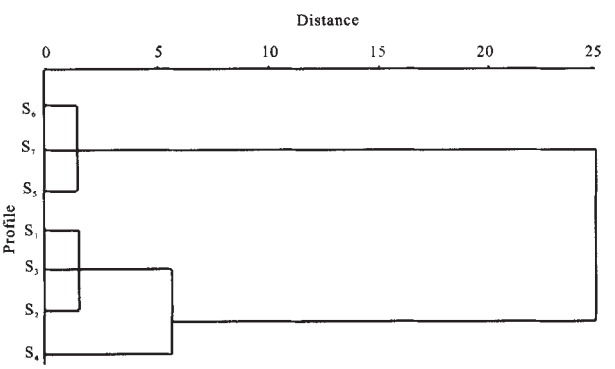

Fig. 2 The classification of soils according to the soil humus compositions and properties

5 CONCLUSIONS

There are two points needing further explanation: firstly, from macroscopic point of view, any two kinds of neighboring physical geography units transfer to each other gradually and it's impossible to separate them completely with the geometric line. While from theoretical and microscopic point of view, there must be a boundary (narrow in width), and there must be secondary differentiation of physical geographical feature on the both sides of the boundary. Discovering and describing the boundary precisely provides important theoretical and practical significance. So the research of the physical geographical boundary is the focus in

physical geography. There is enough scientific evidence showing that the north boundary of subtropical zone on the south slope of Funiu Mountain lies at between 900m and 1000m above sea level. But where is the precise height requires further research. Secondly, Funiu Mountain spreads several hundreds kilometers from west to east, west higher and east lower and the regional physical condition is greatly different. So it's impossible that the heights of the north boundary of subtropical zone on different longitudes are the same. Generally speaking, a law occurs that it's higher in the west and lower in the east.

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