Characterization of Soil Physical and Chemical Properties in Beijing Urban Forest

XiangYu Meng[a], Li DONG[b]

Beijing Forestry University, Beijing, 100083, China

[a]mengxy@bjfu.edu.cn, [b]dongli@bjfu.edu.cn

Keywords: Urban forest, Urban forest soil, Soil organic matter

Abstract: In order to study the characteristics and change patterns of soil physicochemical properties of different community types in Beijing urban forests, this study conducted a comparative analysis of soil physicochemical properties of different community types in urban forests in Beijing. The results showed that the soil physicochemical properties and organic matter content of the current Beijing urban forest were poor; in addition, by analyzing the differences of soil physicochemical properties, except for soil pH, the soil physicochemical indexes of different community types were significantly different ($P<0.05$), the soil chemistry of mixed broadleaf forests is significantly higher than that of other community types. The soil pH, SBD and SWC showed an increasing trend with the deepening of soil depth, while the TP, OC, OM, TN, TP, AP and AK showed a decreasing trend. Therefore, the community design of the subsequent urban forest should focus on creating a composite community type, appropriately retaining understory plants, increasing the organic matter content of the soil, and forming a good synergistic effect with the soil.

1. Introduction

Urban forests, as an important component of urban ecosystems, play an active role in preserving urban species diversity and ecosystem stability[1]. Among them, plant-environment relationships are one of the hot issues in current ecological research[2][3]. It was found that for regional scale and smaller scales (e.g., community scale)[4][5], plant diversity is more influenced by environmental factors such as microtopography, forest stand and soil nutrients[6][5]. Soil physicochemical properties are fundamental factors in maintaining plant species richness[7] and are widely considered to be correlated with plant diversity[8], thus the relationship between soil physicochemical properties and plant diversity interactions is an important issue explored in ecology[9][10].The reason for this is that soil physicochemical properties not only reflect soil fertility status and are an important indicator to characterize soil quality, but also have an important impact on forest productivity[11] The study of soil physicochemical properties in different community types of urban forests can help to elucidate the interaction and mechanism between above-ground vegetation and soil, the whole ecosystem process of forest and soil, and can provide scientific basis for the subsequent design of urban forests[12][13].

The Beijing Municipal Government has implemented a million-mu afforestation project in the plains since 2012, which has had a significant impact on the urban forest ecosystem and the landscape appearance of forests in the plains of Beijing[14]. As an important part of the urban forest in Beijing, there is a lack of research on the physical and chemical properties of the soil in this region. Therefore, this study aims to investigate the variation of soil physicochemical properties in different community types and the characteristics of soil physicochemical properties in different community types, and the results of this study can provide scientific guidance for the design of urban forest.

2. Research Sample Sites and Methods

The stand types in the sample plots of this study were divided into 30 community types (Table

1).

Tab. 1 Community types of the study sample sites

Number	Name	Abbreviation	Number	Name	Abbreviation
1	*Betula platyphylla* forests	BPF	16	*Diospyros kaki* forests	DKF
2	*Robinia pseudoacacia* forests	RPF	17	*Robinia pseudoacacia* ‘idaho’ forests	RPIF
3	*Acer truncatum* ‘congsheng’ forests	ATCF	18	*Fraxinus pennsylvanica* forests	FPF
4	*Eucommia ulmoides* forests	EUF	19	*Ginkgo biloba* forests	GBF
5	*Platanus acerifolia* forests	PAF	20	*Ulmus pumila* forests	UPF
6	*Styphnolobium japonicum* forests	SJF	21	*Acer truncatum* forests	ATF
7	*Salix matsudana* forests	SMF	22	*Catalpa ovata* forests	COF
8	*Robinia pseudoacacia* f. *decaisneana* forests	RPDF	23	*Pinus bungeana* forest	PBF
9	*Ulmus pumila* ‘jinye’ forests	UPJF	24	*Platycladus orientalis* forest	POF
10	*Koelreuteria paniculata* forests	KPF	25	*Juniperus chinensis* forests	JCF
11	*Populus tomentosa* forests	PTMF	26	*Pinus tabuliformis* forests	PTF
12	*Quercus mongolica* forests	QMF	27	*Cedrus deodara* forests	CDF
13	*Ailanthus altissima* ‘qiantou’ forests	AAQF	28	Deciduous broad-leaf mixed forests	DDMF
14	*Catalpa bungei* forests	CBF	29	Broadleaf and coniferous forests	BCF
15	*Populus davidiana* forests	PDF	30	Coniferous mixed forests	CMF

2.1 Soil Sample Collection

Sampling was carried out by a combination of systematic sampling and typical sampling methods, and the sampling points in this study were set within the plant community sample plots (H2, H3 and H5 in Fig. 1 are soil collection sample points)[15].

Soil samples were collected according to the national forestry standard[16]. The study was conducted from June to October in 2020, and soil samples were collected at different depths(0-20 cm, 20-40 cm and 40-60 cm), with three replicates of each sample, for a total of 3693 soil samples. The soil samples from the same soil layer were mixed and brought back to the laboratory in bags for the determination of soil physical and chemical properties. During the collection process, three in situ soil samples were taken in each of the three soil layers with a ring knife for soil water content determination. Then, the soil samples were preserved for analysis.

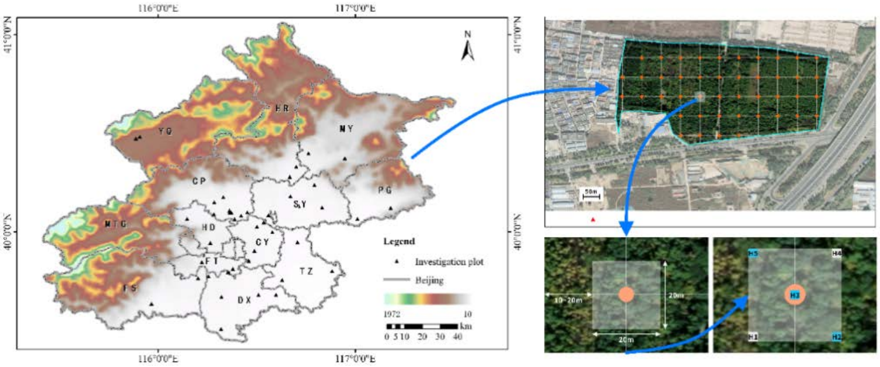


Fig.1 Sample Sites for Plant and Soil Collection

HR (Huairou District), YQ (Yanqing District), MY (Miyun District), PG (Pinggu District), CP (Changping District), SY (Shunyi District), HD (Haidian District), CY (Chaoyang District), TZ (Tongzhou District), FS (Fangshan District), FT (Fengtai District), DX (Daxing District)

2.2 Methods for Determination of Soil Nutrients

Combined with previous studies on soils in urban forests[17], pH, soil bulk density (SBD), total porosity (TSP), water content (SWC), organic matter (OM), organic carbon (OC), total nitrogen (TN), total phosphorus (TP), effective phosphorus (AP), and fast-acting potassium (AK) were selected for measurement and analysis in this study, where porosity included capillary porosity (CP) and non-capillary porosity (NCP), a total of 12 soil factor indicators.

Soil physical and chemical properties were measured in the laboratory, including pH by PHSJ-5 laboratory pH meter, SBD by ring knife sampling method[18], TSP by TYC-1 pore pressure measuring instrument, SWC by drying method and neutron deceleration method[19], TN by semi-micro Kelvin method[20], AK was determined by 0.5 mol-L-1 sodium bicarbonate leaching method[21], OC was determined by potassium dichromate oxidation-spectrophotometric method, OM was determined by multiplying the result of OC by the conversion factor 1.724, TP was determined by sodium hydroxide fusion-molybdenum antimony anti-colorimetric method and AP by Olsen method[22]. In this study, the grades of soil physicochemical properties of Beijing urban forests were evaluated with reference to the relevant criteria in the Chinese Soil Census Technique[23].

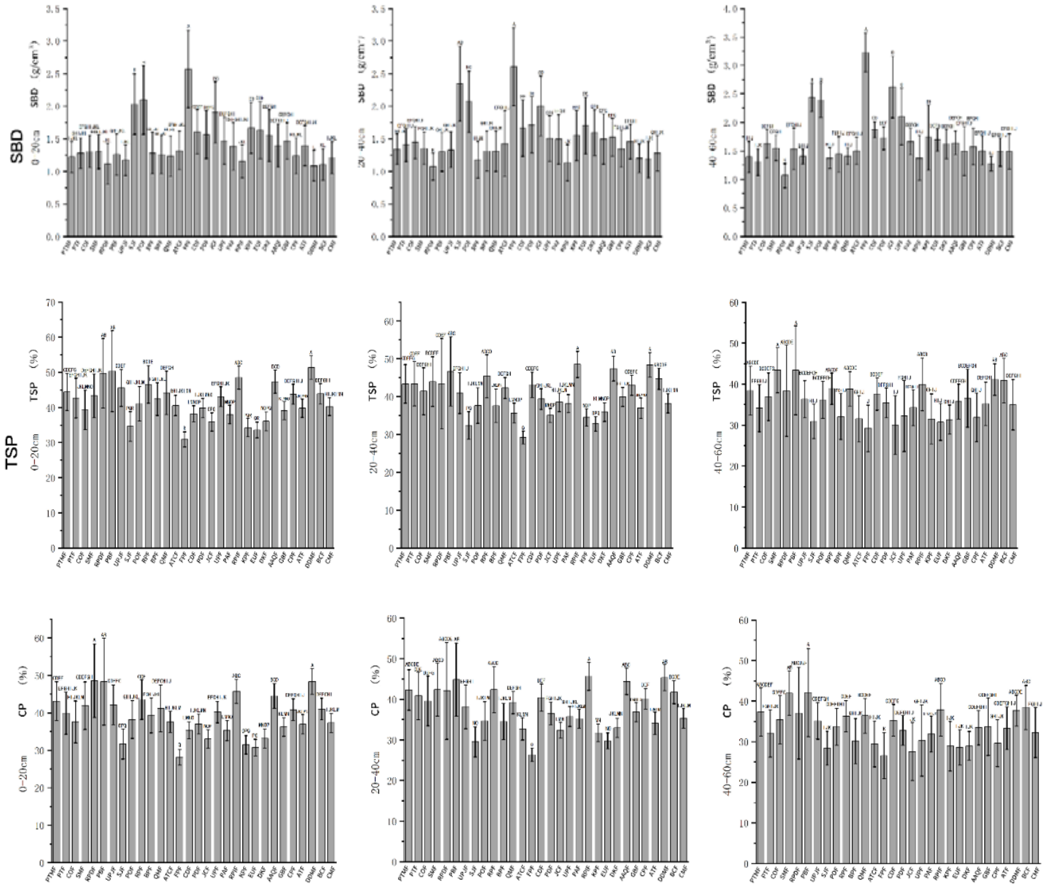
2.3 Data Analysis and Graphing

One-Way ANOVA (SPSS 25 software) and LSD tests were used to analyze the differences in soil physicochemical properties of different urban forest communities ($P<0.05$), and multiple comparisons were used for significance markers; correlation analysis plots were produced using Origin 2019.

3. Characteristics of Physical and Chemical Properties of Soils in Beijing Urban Forests

4. 1 Soil Physical Properties

The result shows that soil physical properties show an overall increasing trend of soil bulk weight and water content with the change of soil depth, while the overall trend of total soil porosity shows a decreasing trend (Fig. 2).



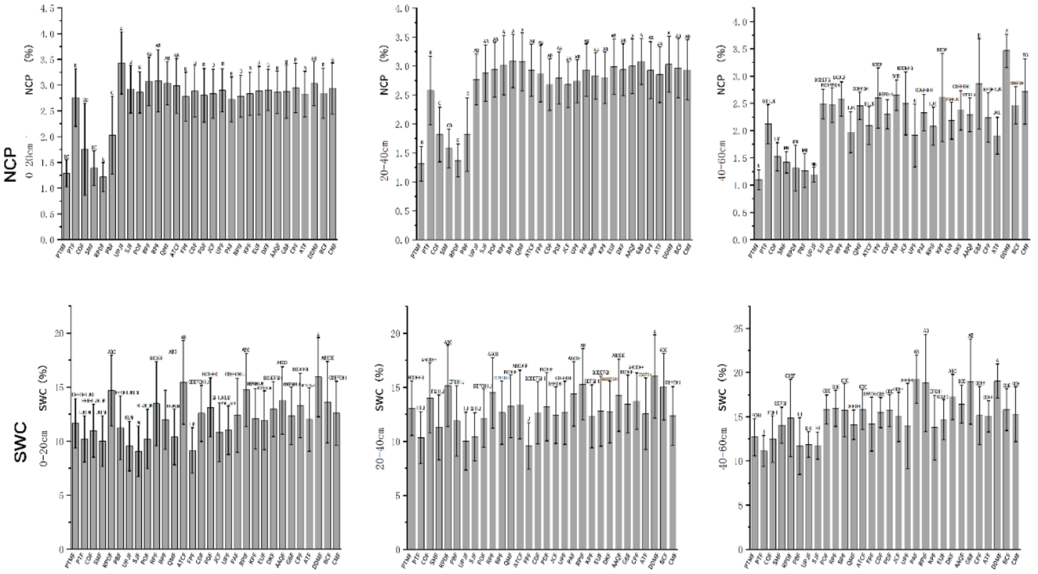


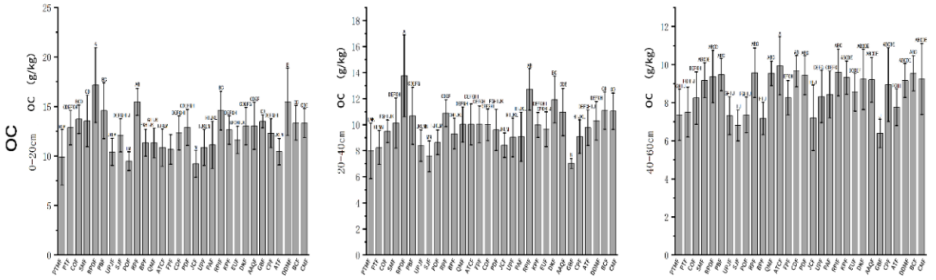
Fig.2 Multiple Comparative Analyses of the Physical Properties of Soils in Urban Forests

Through statistical analysis, the overall soil bulk weight content of the current Beijing urban forest ranged from 1.07±0.21 g/cm^3 to 3.23±0.33 g/cm^3, but the difference in soil bulk weight between 20-40 cm and 40-60 cm soil layers was not extremely significant. While the total soil porosity content ranged from 29.19±5.48% to 51.393±3.317%, 20 community types had total soil porosity in the normal range (total soil porosity is generally considered to be 40%-50% and structurally good). The overall soil water content of Beijing urban forest ranged from 9.050±2.347% to 19.44±2.77%, with a wide range of data fluctuation and some communities (had higher soil water content in the 20-40 cm than in the 40-60 cm soil layer.

4.1 Soil Organic Carbon and Organic Matter Characteristics

Through statistical analysis, the current SOC content of three soil layers in Beijing urban forest ranged from 6.38 ± 0.74 g·kg^{-1} to 17.163 ± 3.771 g·kg^{-1} (Fig. 3), and the OC content showed a decreasing trend with the change of soil depth. The trend of OM content was consistent with that of OC, and its fluctuation range was between 11.00±1.27 g·kg^{-1} and 29.588±6.501 g·kg^{-1}, and most of them belonged to the level 4 soil organic matter level (lower middle) with reference to the assessment standard of the Chinese Soil Census Technique.

The results of the multiple analysis showed that the OC and OM contents of *R. pseudoacacia* f. *decaisneana* forests, Broadleaf and coniferous forests and *R. pseudoacacia* forests were significantly ($p<0.05$) higher than those of other community types, while the OC and organic matter contents of *P. tomentosa* forests and *J. chinensis* forests were the lowest in quantity among the 30 community types and differed significantly ($p<0.05$) from the numerical contents of other community types.



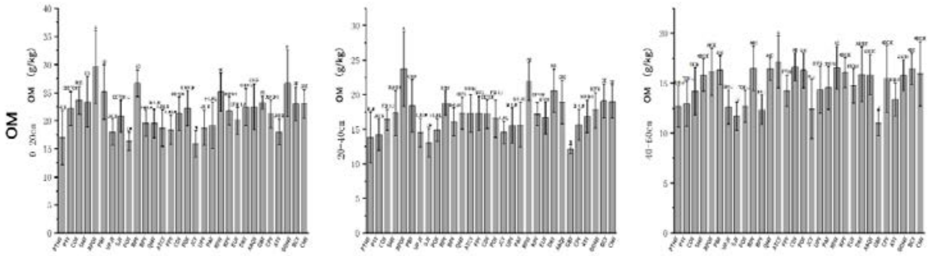
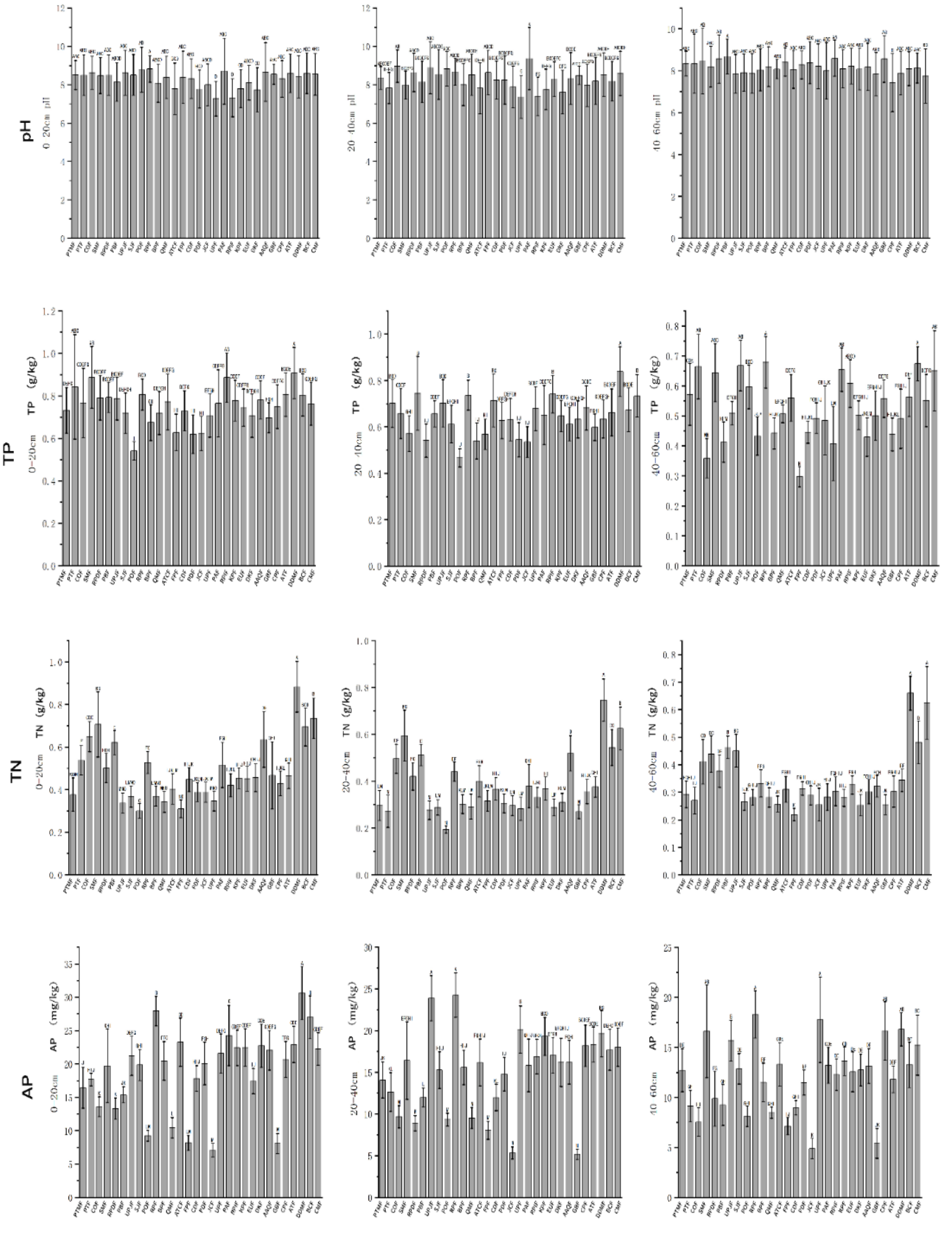


Fig.3 Multiple Comparative Analyses of Oc and om in Different Urban Forest Communities.

4.2 Characteristics of Soil Chemical Properties

The soil chemical properties of the current Beijing urban forest show regular changes with the change of soil depth, among which pH shows an increasing trend with the change of soil depth, and total nitrogen, total phosphorus, effective phosphorus and fast-acting potassium show a decreasing trend.Among them, the pH values of different soil layers in Beijing urban forest were basically above 7.5; the TN, TP, AP and AK in deciduous broad-leaf mixed forests showed higher levels in all communities, and were significantly ($p<0.05$) higher than other community types (Fig. 4).



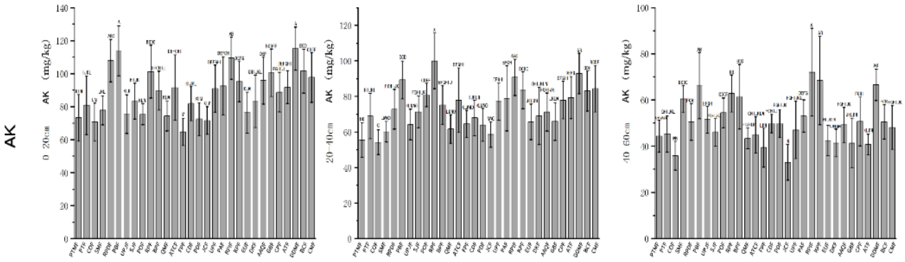


Fig.4 Multiple Comparative Analyses of Soil Chemistry in Different Urban Forest Communities.

By benchmarking against the Chinese Soil Census Technique[23], the current TN levels in different soil layers of Beijing urban forests ranged from g·kg $^{-1}$ to 0.884 ± 0.119 g·kg $^{-1}$; TP levels ranged from 0.30 ± 0.04 g·kg $^{-1}$ to 0.908 ± 0.121 g·kg $^{-1}$; AP content ranged from 4.85±1.02 mg·kg^{-1} to 30.634±3.994 mg·kg^{-1}; AK content ranged from 33.38±7.67 mg·kg^{-1} to 115.244±13.053 mg·kg^{-1},The chemical properties of the soil belong to 3-5 levels, the nutrient content of the soil is low.

5. Discussion

Differences in soil physicochemical properties determine differences in community structure[2]. In this study, except for soil pH, there were significant differences ($p < 0.05$) in soil physicochemical indicators between community types, which indicated that community type differences could have significant effects on soil physicochemical properties. Previous studies found that soil physicochemical properties of mixed forests were better than those of pure forests [24].The present study is similar to the results of previous studies, the soil physicochemical properties of the mixed broadleaf forest are better than those of other community types and mixed forests reflected a stronger advantage[13] .It has been shown that OM and TN have significant effects on understory plant diversity[7], they are important soil factors that affect the diversity of understory plants, and they indirectly influence understory diversity by regulating soil properties. Therefore, in the process of urban forest conservation, attention should be paid to regulating and improving soil nutrients, and retaining dead litter in the forest to increase soil organic matter content, so as to provide good nutrient supply for the growth of understory plants.

Acknowledgements

This article is a special research project of National Natural Science Foundation of China and Xicheng District Finance Science and Technology of Beijing.Project: National Natural Science Foundation of China (NSFC) Project: (Response of Autophyte Diversity Characteristics and Distribution to Urban Green Space Environmental Heterogeneity), No.: (32171860); Beijing Xicheng District Financial Science and Technology Special Project (based on the research on key technologies of urban forest conservation and management in healthy and sustainable Xicheng District), No.: (XCSTS-SD2021-09).

References

[1] Condit, Richard, Ashton, et al., 2000. Spatial Patterns in the Distribution of Tropical Tree Species. [J]. Science. 288(5470), 1414-1418.

[2] Maina G. G., Brown J. S., Gersani M. 2002. Intra-plant versus inter-plant root competition in beans, Avoid ance, resource matching or tragedy of the commons. Plant Ecology. 160, 235-247.

[3] Rota E., Caruso T., Bargagli R. 2014. Community structure, diversity and spatial organization of enchytraeids in Mediterranean urban holm oak stands[J]. European Journal of Soil Biology. 62:83-91.

[4] Guisan A., Zimmermann N. E. 2000. Predictive habitat distribution models in ecology[J]. Ecological Modelling, 135(2-3):147-186.

[5] Lin L., Dai L., Lin Z. B., et al. 2021. Plant Diversity and Its Relationship with Soil Physicochemical Properties of Urban Forest Communities in Central Guizhou. , 30(11):2130-2141.

[6] Wu J. P., Liu Z. F., Wang X. L., et al. 2011. Effects of understory removal and tree girdling on soil microbial community composition and litter decomposition in two Eucalyptus plantations in South China. Functional Ecology. 25, 921-931.

[7] Yan W. M., Sun B., Pei N. C. et al. 2019. Correlation analyses on plant diversity and soil physical-chemical properties between evergreen broad-leaved plantations and natural secondary forests in North Guangdong, China [J]. Ecology and Environmental Sciences, 28(5): 898-907

[8] Weigel R., Gilles J., Klisz M., et al. 2019. Forest understory vegetation is more related to soil than to climate towards the cold distribution margin of European beech. Journal of Vegetation Science.30(4): 746-755.

[9] Mori A., Takeda H. Effects of undisturbed canopy structure on population structure and species coexistence in an old-growth subalpine forest in central Japan[J]. Forest Ecology & Management, 2004, 200(1-3):89-100.

[10] Tilman D., Reich P. B., Lsbell F. 2012. Biodiversity impacts ecosystem productivity as much as resources, disturbance, or herbivory[J]. Proceedings of the National Academy of Sciences of the United States of America. 109(26), 10394-10397.

[11] Marzaioli R., D’ascoli R., De Pascale R.A. 2010. Rutigliano FA. Soil quality in a Mediterranean area of southern Italy as related to different land use types [J]. Appl Soil Ecol. 44 (3): 205-212

[12] Shukla M. K., Lal R., Ebingreb M. 2006. Determining soil quality indicators by factor analysis [J]. Soil Tillage Res. 87 (2): 194-204

[13] Liu J.T., Gu Z.J., Shao B. et al. 2016. N–P stoichiometry in soil and leaves of Pinus massoniana forest at different stand ages in the subtropical soil erosion area of China [J]. Environ Earth Sci.75 (14): 1091

[14] Wang C., Jia B., Qie G.F, et al. 2017. Effect and Development Countermeasures of Beijing Plain Afforestation[J]. Journal of Chinese Urban Forestry. 15(6): 6-11.

[15] Li G. 2014. Handbook of biodiversity monitoring techniques [M]. China Environment Press.

[16] LY/T 1210-1999, Collection and preparation of forest soil samples [S].

[17] Zhang K.X., Shang K.K., Da L.J. 2015. Soil quality comprehensive assessment of different plant communities in Shanghai green belt[J]. Journal of Nanjing Forestry University (Natural Science Edition). 58(03): 71-77.

[18] LY/T 1215-1999, Determination of moisture-physical properties of forest soils [S].

[19] LY/T 1213-1999, Determination of water content of forest soils [S].

[20] LY/T 1228-1999, Determination of total nitrogen in forest soils [S].

[21] LY/T 1233-1999, Determination of total phosphorus in forest soils [S].

[22] HJ 615-2011, Determination of organic carbon in soil by oxidation-spectrophotometric method with potassium dichromate [S].

[23] National Soil Census Office. 1992. Soil census techniques in China [M]. Agricultural Press.