Status of urban vegetation in Guangzhou City

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Abstract: According to a survey for the urban vegetation of Guangzhou, urban vegetation has a significantly difference from natural vegetation because of intense human impacts. The research was conducted in a synthetic survey for soil, species diversity, roadside trees and ecological function of urban vegetation in Guangzhou City. The results showed that: (1) soil densities of urban roadside and park forests were higher than mean density of natural forest soil. The pH values of soil in urban roadside were higher too, and the content of organic matter and the concentration of nitrogen were lower. (2) Species diversity of urban vegetation was lower. The most number of species was only 16 species in tree layers of urban forest. (3) Tree growth was limited by narrow space in high-density urban area, where the trees with defects and disorders were common. (4) Comparing with mature natural forests, the productivity of urban vegetation was lower. The effect of urban vegetation on balance of carbon and oxygen were influenced by the low primary production of urban vegetation. Therefore, the growth condition for urban vegetation should be improved. Biodiversity, primary production and ecological function should be increased for urban vegetation in order to improve urban eco-environment.

Keywords: Urban vegetation; Status; Human impact

CLC number: S731.2 **Document code**: A **Article ID**: 1007-662X(2003)03-0249-04

Introduction

Urban vegetation includes forest, shrub land, grassland, orchard, hedge, and farmland etc. (Wang 1998). With the fast development of urbanization and industrialization for recent more than 20 years in Pearl River Delta, urban environmental quality gradually declined. Urban vegetation plays important roles in improving urban landscape and eco-environment (Beckett *et al.* 1998; Rowntree & Nowak 1991; Bradshaw *et al.* 1983; He & Ning 2002; Laurie 1979). Environmental roles of urban vegetation largely depend on biomass and production of vegetation, which are related to growth condition and ages of vegetation (Rowntree & Nowak 1991; Fang *et al.* 1996; Guan and Chen 2003). In urban area, human activities are intense due to high-density population, thus urban vegetation is largely affected by human activities and has a significant difference from natural vegetation (Guan *et al.* 1998; He & Ning 2002; Schmid 1975). Generally, the biomass, production and species diversity of urban vegetation would be reduced owing to human impacts, thereby the effects of urban vegetation on environment would be also declined comparing with that of natural vegetation, and it is lack of relevant synthetic research. This paper describes the properties of urban soil, species diversity of urban forest, roadside trees, effect of urban vegetation on balance of carbon and oxygen, and impact of human activities, basing on the research for urban vegetation of Guangzhou City. The study may be helpful for the plan and management of urban vegetation and the improvement of its ecological effect in cities.

Study area and survey outline

Study area

This study was conducted in the 8 old districts of Guangzhou, which include Yuexiu, Dongshan, Huangpu, Liwan, Fangcun, Haizhu, Baiyun, and Tainhe districts. The total area is 1 443.6 km^2, the climate of urban area of Guangzhou is governed by the monsoons, the annual mean temperature is 21.97 °C, the annual mean relative humidity is 77%, and the annual mean rainfall is about 1 780 mm. The vegetation cover rates are 24.1% in built-up area and 66.7% in total area.

Survey outline

The density, structures, pH values, organic matter, nitrogen and phosphorus of topsoil (0-20 cm) were measured in 9 roadsides and 8 urban park forests. Species diversity of communities in 7 urban park forests, which were disturbed by different intense human activities, was investigated by 10 plots of 100 m^2 for each community. A detail survey for characters and problems of 1 356 roadside trees was conducted in 14 streets of Liwan high-density old town. Effect of urban vegetation on balance of carbon and oxygen as well as impact of human activity were assessed based on estimation of biomass and primary production of urban vegetation of Guangzhou

Foundation item: This paper was supported by the Natural Science Foundation of Guangdong Province (021740) and Guangdong Environmental Protection Foundation (2001-18)

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Email: eesgds@zsu.edu.cn

Received date: 2002-12-25

Responsible editor: Song Funan

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Results and discussion

Physical and chemical properties of urban soil

According to a survey in urban districts of Guangzhou, mean soil densities in park forest and roadside were 1.41 $g\cdot cm^{-3}$ and 1.59 $g\cdot cm^{-3}$, respectively (Table 1), which were higher than that of natural soil (1.3 $g\cdot cm^{-3}$). The root growth of plant would be restricted if soil density was over 1.75 $g\cdot cm^{-3}$ for sandy soil and 1.55 $g\cdot cm^{-3}$ for clay soil (Craul 1994). In urban districts of Guangzhou the topsoil densities of more than a half were over 1.55 $g\cdot cm^{-3}$, of which 4 densities of topsoil (consisted of 44.4% roadside soil samples) were over 1.75 $g\cdot cm^{-3}$, which may be caused by human trampling. Thus it can be concluded that plant growth had been influenced.

Table 1. Physical and chemical properties of top soil of different vegetation types in urban districts of Guangzhou City

Sites	Soil profile	Soil density	<0.01 mm clay /%	pH	Organic matter /%	Total nitrogen /%	Total phosphorus /%	C/N
Roadside soil	1	1.79	33	7.23	0.84	0.076	0.011	6.4
	2	1.92	27	7.63	1.28	0.106	0.011	7.0
	3	1.80	21	7.42	0.14	0.014	0.045	5.8
	4	1.46	15	8.03	2.71	0.065	0.033	24.2
	5	1.00	10	7.73	6.03	0.112	0.007	31.2
	6	1.40	17	8.49	3.27	0.053	0.003	35.8
	7	1.57	27	8.12	1.22	0.043	0.022	16.5
	8	1.81	21	6.16	0.38	0.044	0.030	5.0
	9	1.56	33	4.28	1.22	0.143	0.051	4.9
	Mean	1.59	23	7.23	1.90	0.073	0.024	15.2
Urban park forest soil	10	1.48	39	4.44	2.53	0.101	0.009	14.5
	11	1.52	28	4.10	3.91	0.169	0.034	13.4
	12	1.30	46	4.02	5.25	0.217	0.014	14.0
	13	1.31	29	3.78	4.27	0.141	0.018	17.6
	14	1.36	28	3.85	4.81	0.184	0.016	15.2
	15	1.67	29	4.16	1.24	0.062	0.008	11.6
	16	0.97	30	5.89	2.01	0.113	0.009	10.3
	17	1.65	19	4.44	3.89	0.155	0.045	14.6
	Mean	1.41	31	4.34	3.49	0.142	0.019	14.1

Red soil is generally acidic in southern China, its pH values range from 4.0 to 5.5 (Yuan 1983). In natural vegetation, the contents of organic matter in top layer of red soil are $(4.04\pm1.41)\%$, the concentration of total nitrogen are $(0.167\pm0.0061)\%$, and ratios of carbon and nitrogen are $(14.7\pm3.82)\%$ (Wen & Lin 1983). In urban districts of Guangzhou, the pH values, content of organic matter and concentration of total nitrogen were in normal range for topsoil of urban park vegetation, but in most topsoil of roadside, pH values were obviously high, the contents of organic matter and concentration of total nitrogen were relatively low, and ratios of carbon and nitrogen were extremely large or small. That is because the concentration of organic carbon in some roadside soils, which contain much coal slag and living garbage, were very high, and the concentration of nitrogen were lower. Therefore, ratios of carbon and nitrogen were very high. For some other roadside soil, the natural top-layer soil was taken off, thus the contents of organic matter and ratio of carbon and nitrogen of topsoil were also very low. In addition, mean content (23%) of <0.01 mm clay of roadside soil was lower than that (31%) of urban park vegetation.

Species diversity of urban forest

In urban distracts of Guangzhou, the original vegetation has been destroyed for the construction of city, most of current vegetation belongs to artificial vegetation types. Species diversity of this artificial vegetation was relatively lower (Table 2). The most number of species was only 16 species, and the indexes of species diversity ranged from 0 to 2.93 for tree layers in 7 forest communities of urban parks. Moreover the number of species in shrub layers is 35 at most, and its indexes of species diversity ranged from 0 to 3.88. Both the number of species and the indexes of species diversity in urban park forest of Guangzhou were obviously lower than those of nature evergreen broad-leaved forest (Peng & Chen 1983). It is indicated that species diversity tends to decline in urban vegetation due to human impacts. For example, in Liuhuahu Park there was only one species and its undergrowth was destroyed and index of species diversity was 0 in *Ficus microcarpa* forest. However, species diversity gradually increased with the development of communities, when the communities were protected in some urban area. For example, in 3 communities of Yuexiu Park there were 15-16 species for tree layers in 1 000 m^2 and 17-35 species for shrub layers in 250 m^2, which were about 1/3 of species for tree layers and 1/2 of species for shrub layers comparing with good natural evergreen broad-leaved forest.

Table 2. Species diversity of forest in urban area of Guangzhou and its neighboring area

Areas	Locations	Community[1)]	Tree layer				Shrub layer			
			Area /m²	Species	Total plant	Species diversity[2)]	Area /m²	Species	Total plant	Species diversity[2)]
Guangzhou	Xiaogang Park	(1)	1000	4	70	1.27	250	7	51	2.10
	Liuhuahu Park	(2)	1000	1	17	0	250	1	1	0
	Martyr Tombs	(3)	1000	2	37	0.64	250	13	36	3.27
	Huanghuagang Park	(4)	1000	8	101	1.22	250	24	443	3.65
	Yuexiu Park	(5)	1000	15	157	2.75	250	35	680	3.88
	Yuexiu Park	(6)	1000	16	143	2.90	250	17	644	2.77
	Yuexiu Park	(7)	1000	15	92	2.93	250	25	1280	1.48
Zhaoqing	Dinghu mountain	(8)	1000	61	1310	4.50	250	68	1041	4.43
Fengkai[3)]	Heishiding	(9)	1000	50	346	4.57	250			
Ruyuan[3)]	Jigongkeng	(10)	1000	48	206	4.45	250			

[1)] (1) *Cinnamomum camphora* + *Pinus elliottii* forest; (2) *Ficus microcarpa* forest; (3) *Pinus massoniana* forest; (4) *Eucalyptus tereticornis* forest; (5) *Pinus massoniana* mixed needle-broad leaves forest; (6) *Acacia confusa* mixed broad leaves forest; (7) *Cinnamomum burmannii* forest; (8) *Castanopsis chinensis* + *Schima superba* + *Cryptocarya chineniss* forest; (9) mountain evergreen broad-leaved forest; (10) evergreen broad-leaved forest. [2)] Species diversity is Shanon—Wiener index. [3)] Data is from Peng shaolin and Chen Zhanghe (1983).

Roadside trees in high-density urban area

In general, there are many problems for roadside trees in urban area, especially in high-density urban area (Jim 1986, 1992). A detailed survey for 1 356 roadside trees was conducted in 14 streets of high-density Liwan area of Guangzhou, in which there were a series of defects and disorders for roadside trees (Table 3). The results showed that the trees along roadside of high-density urban area were often affected by narrow space and intensive human impacts.

Effect of urban vegetation on balance of carbon and oxygen

The effect of urban vegetation on balance of carbon and oxygen is related to biomass and primary production of vegetation (Fang *et al.* 2001; Potter, 1999). The biomass and production of urban vegetation of Guangzhou were estimated by dimension analysis, tree trunk volume, and the relationship between biomass and net primary production (NPP) and so forth (Table 4) (Fang *et al.* 1996; Guan 2003). The plant biomass was 2.88×10^6 t; NPP was 1.06×10^6 $t\cdot a^{-1}$; total carbon content was 1.33×10^6 t; mean carbon content was 13.78 $t\cdot hm^{-2}$. Total amounts of fixing carbon and making oxygen were 0.46×10^6 $t\cdot a^{-1}$ and 1.23×10^6 $t\cdot a^{-1}$, respectively; and the mean amounts were 4.80 $t\cdot hm^{-2}\cdot a^{-1}$ and 12.79 t/ $t\cdot hm^{-2}\cdot a^{-1}$, respectively (Table 5).

Mean biomass and NPP of urban forest were respectively 58.49 $t\cdot hm^{-2}$ and 10.69 $t\cdot hm^{-2}\cdot a^{-1}$, which were 15.4% and 46.1% of those of southern subtropical evergreen broad-leaved forest on Dinghushan (Peng & Zhang 1995). Therefore, the effect of Guangzhou urban vegetation on the balance of carbon and oxygen would be increased greatly if it could be conserved and improved in some way.

Table 3. Frequency of trees with defects and disorders in high-density old town of Guangzhou

Items	Defects or Disorders	Tree number	% of total trees
Roots or Surfaces	Cracked paving	46	3.4
	Heaved paving	32	2.4
	Exposed roots	56	4.1
	Compacted soil	1356	100
Trunk	Leaning	413	30.5
	Curved	94	8.9
	Large wound	338	24.0
	Tree-tie injury	32	2.4
	At or beyond kerb	493	36.4
	Vandal evidences	520	38.3
Foliage or Crown	Sparse	37	2.7
	Unbalance crown	311	22.9
	Stunted	30	2.2
	Advertisement- sign conflict	2	0.1
Branch	Low	18	1.3
	V-crotch	188	13.9
	Branch stub	221	16.3
	Lost limb	32	2.4
	Fungal stool	64	4.7

Conclusion

Urban vegetation is intensely affected by human activities, and the physical and chemical properties of urban soil have been changed. The vegetation suffers human injury and space restriction etc.. Ecological function and species diversity of vegetation also tends to decline. Therefore, urban vegetation of Guangzhou should be conserved, and its species diversity and ecological function should be increased. In order to improve urban eco-environment, protecting vegetation and introducing local tree species should be conducted in cities.

Table 4. Biomass and net primary productivity of urban vegetation in Guangzhou

Locations	Area /hm^2	Biomass /t	NPP /t·a^{-1}	Mean Biomass /t·hm^{-2}	Mean NPP /t·hm^{-2}·a^{-1}
Built-up area	5763	392495	64948	68.11	11.27
Urban park	996	86089	12319	86.43	12.37
University	505	39215	6083	77.65	12.04
Roadside	295	26248	3423	88.98	11.60
Other	3967	240943	43123	60.74	10.87
Unbuilt-up area	90596	2482655	993174	27.40	10.96
Forest	33600	1909731	355848	56.84	10.59
Shrubland & sparse woodland	429	8477	2826	19.76	6.59
Orchard	10837	256837	99700	23.70	9.20
Cultivated land	45730	307610	534800	6.73	11.69
All area	96359	2875150	1058122	29.84	10.98

Table 5. Content of carbon and the amounts of fixing carbon and making oxygen in urban vegetation of Guangzhou

Locations	Plant carbon content /t	Mean plant carbon content /t·hm^{-2}	Carbon mass in NPP t·a^{-1}	Mean carbon mass in NPP /t·hm^{-2}·a^{-1}	Oxygen made in NPP /t·a^{-1}	Mean oxygen made in NPP /t·hm^{-2}·a^{-1}
Built-up area	184983	32.10	29165	5.06	77676	13.48
Urban park	42559	42.73	5789	5.81	15422	15.48
University	18417	36.47	2742	5.43	7305	14.46
Roadside	11666	39.55	1480	5.02	3943	13.37
Other	112341	28.32	19154	4.83	51026	12.86
Unbuilt-up area	1143666	12.62	433459	4.78	1154734	12.74
Forest	894015	26.61	160116	4.76	426549	12.69
Shrubland & sparse woodland	3678	8.78	1222	2.85	3255	7.59
Orchard	114164	10.53	43120	3.98	114872	10.60
Cultivated land	131719	2.88	229001	5.01	610058	13.34
All area	1328649	13.78	462624	4.80	1232430	12.79

Acknowledgements

The author wishes to express their sincere gratitude to Professor Qin Chao-feng and Mr. Ding Jian for their helps with fieldwork.

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