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How Well Do Three Tree Species Adapt to the Urban Environment in Guangdong-Hongkong-Macao Greater Bay Area of China Regarding Their Growth Patterns and Ecosystem Services?

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Abstract: It is predicted that global change combined with urbanization will impact increasingly on the society and terrestrial ecosystem in the Guangdong-Hongkong-Macao Greater Bay Area of China (GBA). In this context, the cities in GBA began to plant a variety of urban trees since 2000 which are considered to play an important role in fixing carbon, improving air quality, reducing noise and providing other ecosystem services. However, data on the growth patterns and ecosystem services of the planted trees remains scarce, which hampers a comprehensive understanding of how well the planted trees adapt to the local urban environment. Therefore, we selected three widely planted tree species in Foshan, one of the core cities in GBA and investigated their tree growth and ecosystem services via a harvest campaign and soil analysis. With the same, fast tree growth as natural forests and the greatest above- and below-ground biomass among the three tree species, *MI* (*Mytilaria laosensis* Lec.) showed a distinguished adaption to the local urban environment in terms of growth patterns, carbon fixation, stabilization against typhoon risk and water uptake capacity against potential drought risk in the future. Although *Cf* (*Chinese fir*) showed reduced diameter at breast height (DBH) and volume development, it significantly increased the total and available potassium in soils to improve the soil quality. The DBH growth of *Sp* (*Slash pine*) decreased between six and 12 years old while it recovered at the age of 12 years, probably suggesting its adaptation might take a longer time. Our results indicated that different trees had different growth patterns and ecosystem services after they were planted in cities. In a harsh urban environment under climate change, precise and comprehensive data on urban trees is necessary, helping to provide different perspectives for urban managers to select appropriate tree species and make policies.

Keywords: biomass allocation; ecosystem service; growth pattern; urban trees

1. Introduction

Urban areas around the world are expanding rapidly and will have more than 60 percent of the estimated world population by the year 2030 [1,2], and in association with which, the impacts of global change have become more serious than in previous decades in cities [3,4]. It is widely acknowledged that urban trees can be a key component in the adaptation of cities to climate change and provide ecosystem services accompanying rapid urbanization [5–7], including improving urban air quality, reducing noise, attenuating storm-water flooding and conserving energy, which have drawn increasing

interest from researchers [8–12]. For example, Nowak et al. estimated the carbon sequestration rate of urban trees in the USA [13], and Grote et al. reported that urban trees helped to improve air quality by facilitating widespread deposition of various gases and particles through the provision of large surface areas as well as through their influence on the microclimate and air turbulence [14]. Besides, urban trees could contribute enormously to thermal comfort because heat loads caused by densely built structures could be reduced via evapotranspiration and shading [15]. Furthermore, Gardiner et al. found that urban trees could change at scales from the cell to the whole plant to acclimate to the wind [16].

There is an increasing demand for data on urban trees; however, multiple factors might prevent researchers from obtaining profound knowledge of the growth and ecosystem services of urban trees. Compared to forest stands, urban trees grow in harsh environments with high temperatures [17], limited rooting space [18], reduced aeration due to impervious pavement [19], and less access to soil moisture and nutrients [20], which might have a complex influence on their growth and ecosystem services. For example, Zhang et al. reported that limited water availability in cities could strongly reduce the fine root development of some urban trees in both vertical and horizontal levels [21]. Pretzsch et al. found that urban climate can both accelerate and slow down tree growth, depending on the climatic zone of the given city [22]. In addition, human activities could not be ignored as these disturbances could affect urban tree growth in different ways [23]. Therefore, it is essential to acquire detailed and accurate information for urban trees which may benefit enormously urban management and planning such as providing guidelines for the selection of appropriate tree species in cities.

With an area over 56,000 km² and a population over 70 million, the Guangdong-Hongkong-Macao Greater Bay Area of China (GBA) is one of the most economic and open regions around the world [23]. In the context of global change and rapid urbanization, GBA is facing increasingly serious environmental challenges and positive actions have to be adopted to ameliorate the negative effects. Foshan, one of the core cities in GBA, started to implement a green city policy, aiming to become a forest city since 2000 [24]. Through planting a variety of tree species in the urban area, the forest coverage rate of Foshan reached 40% in 2010 [25]. However, there still existed some problems which hampered our comprehensive understanding of how well the planted trees adapt to the local environment [26]. Because of the strict protection, i.e., the planted urban trees were usually prevented from researches, information on detailed tree growth was still lacking which resulted in a vague understanding of how they grew and allocated above- and below-ground biomass. Besides, whether the planted trees fit the local edaphic condition was rarely researched which was closely related to how to apply and develop fertilizer policy.

Therefore, with the support of the urban forest management bureau of Foshan, we selected three tree species *Slash pine* (*Pinus elliottii* Engelm. var. *elliottii*), *Chinese fir* (*Cunninghamia lanceolata* (Lamb.) Hook) and *Mytilaria laosensis* Lec. as our research objects which were widely planted in the city [27]. We launched a harvest campaign for the three tree species to measure their detailed growth patterns and to analyze their above- and below-ground biomass allocation. Furthermore, how the selected trees impact the soil's physical and chemical properties was investigated as well. Hence, the specific questions addressed in this study were: (1) How well do the three tree species adapt to urban environment in terms of their volumes, heights and DBH (diameter at breast height)? (2) What are their specific biomass allocation between above- and below-ground compartments? (3) Do they have different impacts on the physical and chemical properties of the soil?

2. Materials and Methods

2.1. Study Site and Trees Selection

This study was performed in the urban green space (22°45'21"–22°46'43"N, 112°37'46"–112°39'34"E) of Gaoming district, Foshan, China, which is under a subtropical humid monsoon climate [28]. With the area around 15000 m² and each tree being planted more

than 3 m away from the others to avoid the mutual effect, this site shows little variation in terms of microclimatic conditions and is ideal for research. *Slash Pine* (*Sp*), *Chinese fir* (*Cf*) and *Mytilaria laosensis* (*Ml*) are three widely-planted tree species in GBA and each of them had over 20 individuals in this green space (Figure 1). Aiming to select the most representative trees of the three species in this area, the diameters at breast height (DBH) and the heights of all the trees were measured with the help of a diameter tape and a clinometer (Haglof Vertex IV, Sweden) during the summer of 2013. The mean DBH and height of all the investigated trees were calculated, and based on which, the three most representative sample trees of *Sp*, *Cf* and *Ml* (nine trees in total) were selected for further analysis.

Figure 1. Illustration of study site in Foshan of GBA, China. The green, red and yellow points represent *Sp*, *Ml* and *Cf*, respectively while the blue ones are the other tree species.

2.2. Measurements of Climate Variables

Climate variables, including highest, lowest and mean temperature ($^{\circ}\text{C}$), precipitation (mm) and max wind speed ($\text{m}\cdot\text{s}^{-1}$) were sampled every 10 min with a weather station (WP3103 mesoscale automatic weather station, China) located at an unshaded site approximately 500 m away from the study site. The data were stored in the logger and copied to our laboratory to produce monthly data. For the past decade, with the mean annual precipitation 3416 mm, the rainfall varied monthly and usually reached peaks in summer which could be over 250 mm. Additionally, the mean and the highest temperature in summer was over 28°C and 35°C , while in winter the mean and lowest temperature was 13.5°C and 4.4°C , which showed a moist and warm environment for trees. The max wind speed fluctuated in different months and ranged from 7.5 to $15.2\text{ m}\cdot\text{s}^{-1}$ generally, which showed a windy circumstance (Figure 2).

Figure 2. Monthly max wind speed ($\text{m}\cdot\text{s}^{-1}$, line graph), monthly totals of precipitation (mm; bar graph) and monthly mean, highest and lowest temperature ($^{\circ}\text{C}$; line graph) for the study site from 2002 to 2014.

2.3. Measurements of Soil Variables

Soil sampling was launched for the three tree species in November using a soil wreath knife (200 cm^3) which aimed to analyze the physical and chemical properties. For each tree, three corings were taken in the distance of 50, 100 and 150 cm to the trunk for replications. For every coring in detail, firstly a 100-cm depth hole was dug by a spade and it was divided into four layers on average, i.e., 0–25, 25–50, 50–75 and 75–100 cm. The soil physical properties were measured according to Li et al. [29]. Soil bulk densities (BD, $\text{g}\cdot\text{cm}^{-3}$) were determined by the mass of soil per unit volume (sum of solids and pore space) and the soil cores were oven-dried at 105°C to obtain field capacity (FC, %). Each soil core was put into a salver to absorb water via filter paper until it reached a steady weight, usually 12 h later to measure saturation moisture content (SMC, $\text{g}\cdot\text{kg}^{-1}$). Then, the soil cores were put on a sand salver and allowed to drain for 2 h in order to calculate soil capillary water content (Scwc). Hence, soil capillary porosity (Scp, %) was calculated according to the equation as:

$$Scp = 0.1 \times Scwc \times ds \quad (1)$$

where ds is the soil density ($\text{mg}\cdot\text{m}^{-3}$). And soil non-capillary porosity (Snpc, %) and soil total porosity (Stp, %) were calculated as:

$$Snpc = 0.1 \times (Smc - Scwc) \times ds \quad (2)$$

$$Stp = Scp + Snpc \quad (3)$$

For soil chemical properties, soil pH was determined in 1:2.5 soil–water slurry using a combination glass electrode. The soil organic matter (SOM, $\text{g}\cdot\text{kg}^{-1}$) was determined by the oil bath- $\text{K}_2\text{Cr}_2\text{O}_7$ titration method. The total nitrogen (TN, $\text{g}\cdot\text{kg}^{-1}$) was determined by the semi-micro Kjeldahl method. The available nitrogen (AN, $\text{mg}\cdot\text{kg}^{-1}$) was determined by a micro-diffusion technique after alkaline hydrolysis. The total phosphorus (TP, $\text{g}\cdot\text{kg}^{-1}$) was determined colorimetrically after wet digestion with $\text{H}_2\text{SO}_4 + \text{HClO}_4$. The available phosphorus (AP, $\text{mg}\cdot\text{kg}^{-1}$) was exacted with $0.5\text{ mol l}^{-1}\text{ NaHCO}_3$ solution (pH 8.5). The total potassium (TK, $\text{g}\cdot\text{kg}^{-1}$) was determined by the Cornfield method. The available potassium (AK, $\text{mg}\cdot\text{kg}^{-1}$) was determined by the $\text{CH}_3\text{COONH}_4$ extraction method [30].

2.4. Measurements of Biomass Allocation and Tree Growth

In December, a harvest campaign was launched in which all the sample trees were excavated carefully with a tree digger and divided into four parts: stem, branch, leaf and root system. Then, the fine root (<2 mm) and coarse root (>2 mm) were separated and washed cautiously to remove the soils and stones on the surface. All these compartments were dried at 65 °C for 72 h and weighed using a balance with an accuracy of up to two decimal places to obtain the dry weight.

A complete stem analysis was carried on for all the felled trees which involved measurements at a series of positions along the stem to deduce their heights and diameters. The sample disks were taken at the nearest representative point below spring branch whorls on trees that had a regular branching pattern. We oriented each disc in the same direction and measured two lines that went through the pith and were at 90 degrees to each other. The mean diameters were calculated and recorded with the height, which were used to produce Height: Age and DBH: Age curves. In addition, tree volumes (V , m^3) were calculated on the basis of species, DBH and height, i.e.,

$$V = C \times 10^{-5} \times DBH^a \times H^b \quad (4)$$

where C , a and b are coefficients related to specific tree species [31–33].

2.5. Statistical Analysis

The software package R (Version 3.4.4) was used for statistical analysis [34]. To investigate the difference between means, two-sampled t-test and analysis of variance (ANOVA) with Tukey's HSD test were used. In all the cases, statistical significance was detected at $p < 0.05$. Where necessary, data were log or power transformed in order to correct for data displaying heteroscedasticity.

3. Results

3.1. Soil Physical and Chemical Properties

It was red soil in the study site, exposed to common visitors. Six variables were measured to describe the soil physical properties of the three tree species (Table 1). Additionally, we not only analyzed the overall soil layer (0–100 cm) but also classified it into four layers on average for significant differences between the three tree species. *Cf* had the highest BD ($1.50 \pm 0.03 \text{ g}\cdot\text{cm}^{-3}$) and lowest Scp ($40.61 \pm 2.20\%$), while *MI* had the highest FC ($26.19 \pm 1.20\%$) and lowest Snpc ($3.07 \pm 0.42\%$). Except for BD and Scp, *Sp* had the lowest values of other indexes in comparison to *Cf* and *MI*. However, except for BD of *Cf* in 75–100 cm ($p = 0.008$) and FC of *MI* in 75–100 cm ($p = 0.019$) which were significantly higher, there were no significant differences between the three tree species in all the corresponding soil layers ($p > 0.05$).

Eight variables were measured to describe the soil chemical properties in different layers of the three tree species (Table 2 and Figure 3), among which SOM, TN, TP and AP showed no significant differences in all the layers. *Sp* had a significantly higher pH value (4.32 ± 0.15 , $p = 0.043$) and significantly lower AN ($59.83 \pm 9.14 \text{ mg}\cdot\text{kg}^{-1}$, $p = 0.025$) in the overall 0–100 cm soil layer. For TK, *Cf* was significantly higher than *Sp* and *MI* in all the layers ($p < 0.01$) except for the layer of 25–50 cm. Additionally in terms of AK, *Cf* was significantly higher in 0–25 cm ($76.00 \pm 16.52 \text{ mg}\cdot\text{kg}^{-1}$), 50–75 cm ($60.00 \pm 13.23 \text{ mg}\cdot\text{kg}^{-1}$) and overall 0–100 cm ($58.17 \pm 9.21 \text{ mg}\cdot\text{kg}^{-1}$).

Table 1. Measured soil physical properties including bulk density (BD, $\text{g}\cdot\text{cm}^{-3}$), field capacity (FC, %), saturation moisture content (SMC, $\text{g}\cdot\text{kg}^{-1}$), soil non-capillary porosity (Snep, %), soil capillary porosity (Scp, %) and soil total porosity (Stp, %) in 0–25, 25–50, 50–75, 75–100 and 0–100 cm layers. The symbol “*” indicates significant differences ($p < 0.05$) between different tree species in the same layers.

Species	Soil Layers (cm)	n	BD ($\text{g}\cdot\text{cm}^{-3} \pm \text{SD}$)	FC (% $\pm \text{SD}$)	SMC ($\text{g}\cdot\text{kg}^{-1} \pm \text{SD}$)	Snep (% $\pm \text{SD}$)	Scp (% $\pm \text{SD}$)	Stp (% $\pm \text{SD}$)
<i>Sp</i>	0–25	3	1.48 $\pm$ 0.09	18.26 $\pm$ 3.14	284.68 $\pm$ 39.85	3.78 $\pm$ 0.71	38.09 $\pm$ 2.84	41.87 $\pm$ 3.49
	25–50	3	1.49 $\pm$ 0.12	18.01 $\pm$ 6.12	274.93 $\pm$ 54.46	2.43 $\pm$ 0.32	38.06 $\pm$ 5.47	40.48 $\pm$ 5.49
	20–75	3	1.43 $\pm$ 0.15	21.33 $\pm$ 6.11	303.64 $\pm$ 63.99	3.41 $\pm$ 0.85	39.39 $\pm$ 6.02	42.80 $\pm$ 5.64
	75–100	3	1.46 $\pm$ 0.08	23.32 $\pm$ 1.43	308.74 $\pm$ 7.64	3.26 $\pm$ 1.38	41.89 $\pm$ 1.50	45.15 $\pm$ 1.30
	0–100	3	1.47 $\pm$ 0.06	20.21 $\pm$ 2.22	1171.99 $\pm$ 95.41	3.22 $\pm$ 0.28	39.36 $\pm$ 2.00	42.58 $\pm$ 1.86
<i>Cf</i>	0–25	3	1.42 $\pm$ 0.08	21.40 $\pm$ 5.25	316.32 $\pm$ 26.21	2.23 $\pm$ 1.18	42.58 $\pm$ 2.98	44.81 $\pm$ 4.05
	25–50	3	1.41 $\pm$ 0.12	22.19 $\pm$ 4.32	342.66 $\pm$ 17.47	4.10 $\pm$ 1.17	44.12 $\pm$ 5.15	48.23 $\pm$ 4.45
	20–75	3	1.54 $\pm$ 0.13	17.06 $\pm$ 4.38	258.37 $\pm$ 54.12	2.78 $\pm$ 0.57	36.63 $\pm$ 5.47	39.41 $\pm$ 4.97
	75–100	3	1.62 $\pm$ 0.05 *	18.37 $\pm$ 5.42	265.98 $\pm$ 57.76	3.78 $\pm$ 1.02	39.11 $\pm$ 7.44	42.89 $\pm$ 8.17
	0–100	3	1.50 $\pm$ 0.03	20.36 $\pm$ 2.14	1183.33 $\pm$ 42.92	3.22 $\pm$ 0.21	40.61 $\pm$ 2.20	43.84 $\pm$ 2.42
<i>MI</i>	0–25	3	1.22 $\pm$ 0.14	26.22 $\pm$ 8.05	397.94 $\pm$ 83.94	3.10 $\pm$ 0.27	44.91 $\pm$ 5.23	48.00 $\pm$ 5.49
	25–50	3	1.49 $\pm$ 0.14	24.65 $\pm$ 1.56	315.90 $\pm$ 28.20	3.11 $\pm$ 0.74	43.59 $\pm$ 0.78	46.70 $\pm$ 0.59
	20–75	3	1.55 $\pm$ 0.02	26.28 $\pm$ 2.73	321.78 $\pm$ 14.80	2.94 $\pm$ 0.92	46.91 $\pm$ 0.91	49.86 $\pm$ 1.83
	75–100	3	1.41 $\pm$ 0.03	28.50 $\pm$ 1.49 *	351.13 $\pm$ 11.50	3.15 $\pm$ 1.67	46.23 $\pm$ 0.86	49.38 $\pm$ 1.26
	0–100	3	1.42 $\pm$ 0.03	26.19 $\pm$ 1.20	1386.75 $\pm$ 68.34	3.07 $\pm$ 0.42	45.41 $\pm$ 0.73	48.49 $\pm$ 1.14

Table 2. Measured soil chemical properties including pH values, soil organic matter (SOM, $\text{g}\cdot\text{kg}^{-1}$), total nitrogen (TN, $\text{g}\cdot\text{kg}^{-1}$), total phosphorus (TP, $\text{g}\cdot\text{kg}^{-1}$), total potassium (TK, $\text{g}\cdot\text{kg}^{-1}$), available nitrogen (AN, $\text{mg}\cdot\text{kg}^{-1}$), available phosphorus (AP, $\text{mg}\cdot\text{kg}^{-1}$), available potassium (AK, $\text{mg}\cdot\text{kg}^{-1}$) in 0–25, 25–50, 50–75, 75–100 and 0–100 cm layers. The symbol “*” indicates significant differences ($p < 0.05$) between different tree species in same layers.

Species	Soil Layers (cm)	n	pH	SOM ($\text{g}\cdot\text{kg}^{-1} \pm \text{SD}$)	TN ($\text{g}\cdot\text{kg}^{-1} \pm \text{SD}$)	TP ($\text{g}\cdot\text{kg}^{-1} \pm \text{SD}$)	TK ($\text{g}\cdot\text{kg}^{-1} \pm \text{SD}$)	AN ($\text{mg}\cdot\text{kg}^{-1} \pm \text{SD}$)	AP ($\text{mg}\cdot\text{kg}^{-1} \pm \text{SD}$)	AK ($\text{mg}\cdot\text{kg}^{-1} \pm \text{SD}$)
<i>Sp</i>	0–25	3	3.93 $\pm$ 0.22	24.30 $\pm$ 10.69	1.14 $\pm$ 0.45	0.31 $\pm$ 0.04	19.47 $\pm$ 5.43	92.90 $\pm$ 25.20	1.33 $\pm$ 0.51	31.00 $\pm$ 19.31
	25–50	3	4.50 $\pm$ 0.42	15.70 $\pm$ 1.97	0.76 $\pm$ 0.04	0.24 $\pm$ 0.06	18.00 $\pm$ 6.02	61.07 $\pm$ 15.85	1.13 $\pm$ 0.61	56.67 $\pm$ 54.85
	50–75	3	4.36 $\pm$ 0.26	12.17 $\pm$ 1.96	0.61 $\pm$ 0.08	0.29 $\pm$ 0.02	16.37 $\pm$ 3.21	43.60 $\pm$ 4.28	1.04 $\pm$ 0.34	21.00 $\pm$ 6.56
	75–100	3	4.19 $\pm$ 0.25	14.63 $\pm$ 3.70	0.62 $\pm$ 0.11	0.31 $\pm$ 0.02	16.77 $\pm$ 2.10	56.07 $\pm$ 18.32	1.00 $\pm$ 0.27	22.00 $\pm$ 17.44
	0–100	3	4.32 $\pm$ 0.15 *	16.04 $\pm$ 2.69	0.77 $\pm$ 0.08	0.28 $\pm$ 0.01	17.05 $\pm$ 4.22	59.83 $\pm$ 9.14 *	1.12 $\pm$ 0.42	30.42 $\pm$ 8.18 *
<i>Cf</i>	0–25	3	4.06 $\pm$ 0.07	23.13 $\pm$ 1.10	1.28 $\pm$ 0.19	0.34 $\pm$ 0.02	30.80 $\pm$ 4.36 *	115.70 $\pm$ 15.70	1.74 $\pm$ 0.45	76.00 $\pm$ 16.52 *
	25–50	3	4.02 $\pm$ 0.03	16.53 $\pm$ 0.55	0.82 $\pm$ 0.10	0.32 $\pm$ 0.06	27.63 $\pm$ 5.35	83.23 $\pm$ 19.24	1.13 $\pm$ 0.44	56.67 $\pm$ 7.64
	50–75	3	4.07 $\pm$ 0.06	15.63 $\pm$ 3.57	0.77 $\pm$ 0.25	0.33 $\pm$ 0.02	29.43 $\pm$ 3.73 *	65.13 $\pm$ 12.44	1.08 $\pm$ 0.27	60.00 $\pm$ 13.23 *
	75–100	3	3.97 $\pm$ 0.06	10.28 $\pm$ 4.36	0.59 $\pm$ 0.26	0.28 $\pm$ 0.02	28.50 $\pm$ 3.93 *	51.43 $\pm$ 18.43	0.91 $\pm$ 0.31	40.00 $\pm$ 8.66
	0–100	3	4.03 $\pm$ 0.02	16.40 $\pm$ 1.98	0.87 $\pm$ 0.19	0.31 $\pm$ 0.03	29.09 $\pm$ 4.27 *	78.88 $\pm$ 6.99	1.21 $\pm$ 0.23	58.17 $\pm$ 9.21 *
<i>MI</i>	0–25	3	3.94 $\pm$ 0.10	33.80 $\pm$ 7.01	1.58 $\pm$ 0.37	0.34 $\pm$ 0.08	15.63 $\pm$ 1.04	141.13 $\pm$ 30.89	1.78 $\pm$ 0.35	26.33 $\pm$ 9.81
	25–50	3	3.97 $\pm$ 0.08	17.80 $\pm$ 5.37	0.84 $\pm$ 0.25	0.28 $\pm$ 0.02	15.97 $\pm$ 2.47	86.00 $\pm$ 9.40	1.13 $\pm$ 0.32	15.33 $\pm$ 4.51
	50–75	3	3.81 $\pm$ 0.27	9.97 $\pm$ 0.22	0.55 $\pm$ 0.02	0.26 $\pm$ 0.04	13.80 $\pm$ 3.00	50.20 $\pm$ 9.21	1.07 $\pm$ 0.17	17.33 $\pm$ 4.04
	75–100	3	3.84 $\pm$ 0.28	9.84 $\pm$ 1.79	0.48 $\pm$ 0.08	0.33 $\pm$ 0.04	15.40 $\pm$ 1.51	47.53 $\pm$ 2.89	0.77 $\pm$ 0.07	14.00 $\pm$ 1.73
	0–100	3	3.89 $\pm$ 0.18	17.85 $\pm$ 0.64	0.86 $\pm$ 0.04	0.30 $\pm$ 0.04	15.20 $\pm$ 1.79	81.21 $\pm$ 6.16	1.19 $\pm$ 0.03	18.25 $\pm$ 2.38 *

Figure 3. Soil chemical variables including SOM ($\text{g}\cdot\text{kg}^{-1}$), TN ($\text{g}\cdot\text{kg}^{-1}$), TP ($\text{g}\cdot\text{kg}^{-1}$), TK ($\text{g}\cdot\text{kg}^{-1}$), AN ($\text{mg}\cdot\text{kg}^{-1}$), AP ($\text{mg}\cdot\text{kg}^{-1}$) and AK ($\text{mg}\cdot\text{kg}^{-1}$) for the three tree species in the overall 0–100 cm layer.

3.2. Development of DBH, Height and Volume

Growth of height, DBH and volume were analyzed for the three tree species for the entire growing period (Figure 4). For *MI*, it showed the highest values of height, DBH and volume among the three tree species ($p < 0.05$). Besides, its fastest development of height and DBH increment occurred from zero to four years old which was the same as the other two tree species. *Sp* exhibited the medium growth of DBH and volume but the lowest height and height increment. *Cf* had a distinctly strong growth of height but probably tended to reach a peak of 10 m. For all the tree species, the height increment speed was significantly reduced after four years old ($p < 0.05$).

Figure 4. Development of height (m), DBH (cm) and volume (m^3) as well as their annual increments of the three tree species (Red: *Sp*; Green: *Cf*; Blue: *MI*). The panel represents the mean value and error bars indicate standard deviation.

3.3. Biomass Allocation and Root:Shoot Ratio

Generally, stem biomass had the largest proportion of the tree, followed by the root system, and branch and leaf had the lowest share (Table 3). With a height of 14.10 ± 0.89 m and DBH of 16.67 ± 0.15 cm, *Sp* had the largest biomass of stem (144.53 ± 7.94 kg) which was the oldest among the three tree species. For *Cf*, its biomass of all the compartments was way less than the other two species. With the same age as *Cf* but younger than *Sp*, *MI* exhibited the highest below-ground biomass (coarse root: 46.70 ± 6.09 kg; fine root: 17.63 ± 4.02 kg). Meanwhile, the highest sum of above-ground biomass was noted for *MI* in the three tree species (*MI*: 191.2 kg; *Sp*: 167.17 kg; *Cf*: 62.34 kg).

Table 3. Height (m $\pm$ SD), DBH (cm $\pm$ SD) and biomass data (kg $\pm$ SD) of the three tree species from the harvest campaign in November, 2013. The above-ground biomass consists of stem, branch and leaf while the below-ground biomass consists of the coarse and fine root.

Species	n	Age	H (m $\pm$ SD)	DBH (cm $\pm$ SD)	Biomass (kg $\pm$ SD)				
					Above-Ground			Below-Ground	
					Stem	Branch	Leaf	Coarse Root	Fine Root
<i>Sp</i>	3	18	14.10 ± 0.89	16.67 ± 0.15	144.53 ± 7.94	11.67 ± 4.02	10.97 ± 6.61	24.83 ± 5.27	13.80 ± 4.91
<i>Cf</i>	3	12	9.50 ± 0.72	11.77 ± 0.67	48.27 ± 8.34	6.97 ± 4.97	7.10 ± 2.07	13.33 ± 7.41	4.47 ± 2.68
<i>MI</i>	3	12	13.23 ± 1.03	15.27 ± 0.80	129.60 ± 22.65	44.73 ± 26.04	16.87 ± 6.17	46.70 ± 6.09	20.23 ± 3.23

Three types of root:shoot ratio were calculated: (1) fine root:leaf biomass ratio, (2) coarse root:branch biomass ratio and (3) below-ground:above-ground biomass ratio (Figure 5). All the root:shoot ratios were significantly different ($p < 0.05$) and *MI* was the highest, which had a larger proportion of root system than *Sp* and *Cf*. Among the three ratios, the below-ground:above-ground biomass ratio of *MI* showed the greatest difference ($p < 0.01$).

Figure 5. Three types of root:shoot ratio: fine root:leaf biomass ratio, coarse root:branch biomass ratio and below-ground:above-ground biomass ratio. Squares, circles and triangles represent trees of *Sp*, *Cf* and *MI* and red, green and blue lines are the fitting regressions, respectively.

4. Discussion

4.1. Growth Patterns of the Three Tree Species

Information on growth patterns for individual trees is an essential tool for forest management [35]. Especially for tree species planted in cities, how growth patterns develop has raised various expectations and concerns [36]. In GBA, the climate was warm and windy, under which the urban trees might face potential drought stress and wind damage as well as other urban disturbances. In our research, *MI* exhibited steady development over time which was in line with Chen's result in a natural forest [27], and it showed significantly higher growth than the other two species in terms of height, DBH and volume. Besides, it grew rapidly in the early stage and the annual DBH and height growth reached peaks in around four years after planting. Moreover in two years later, volume and volume increment started to obtain substantial development which was consistent with previous studies [37,38]. Overall, these results proved *MI* to be a distinguished fast-growing tree species with vigorous growth within the whole growing period, which probably implied that the local urban environment had a minor impact on it.

It was reported that *Cf*'s growth relied on site conditions to a great extent [39]. In southern subtropical China, Zheng et al. found that *Cf*'s DBH and height development reached a peak rapidly and kept steady for over four years under limited disturbance, while under disadvantaged circumstances, its growth could be strongly weakened [40]. In this study, *Cf* had a fast and great development of height as *MI* but the lowest level of DBH increment among the three species, which resulted in the lowest tree volume. Compared to the previous study [40], *Cf* in a natural forest outperformed the trees in our research in terms of the DBH and the volume, implying *Cf* in the urban area is failing to fulfill the growth expectations under a splendid growing environment.

For *Sp*, it exhibited a stable and moderate development of height within the whole period and vigorous growth of DBH in its fast-growing period, which was in line with the results of Zhao's research [41]. Nevertheless, the growing speed of DBH in a natural forest showed a gradually decreasing trend after six years old [42], while that in our research reduced substantially at the same time, which was the most significant difference for *Sp* between the two conditions, probably due to the urban limited environmental conditions. However, the DBH increment recovered and a sharp growth was observed at the age of 12 years. As it was reported that different tree species might take several

years to adapt to its surroundings in cities [43], it could possibly explain that *Sp* regained DBH growth as natural forest stands at the age of 12 years, showing a longer progress of adaptation than *MI*.

4.2. Biomass Allocation and Ecosystem Services

Biomass allocation within a plant, particularly the distribution of biomass among the various organs, is strongly affected by species characteristics, ontogeny and the environment [44]. In this study, various weights of above- and below-ground compartments were quantified including leaf, branch, stem, coarse and fine root and calculated three types of root:shoot ratios, which promoted to understanding not only the different capacities of carbon fixation but also the strategies of biomass allocation of the three tree species. *MI* had the largest total tree biomass, followed by *Sp*, and *Cf* had the least one. In addition, although *MI* trees in this study were only 12 years which were younger than *Sp* of 18 years, it could be speculated that *MI* would have the largest biomass when all the three tree species were at the same age of 18 years on the basis of Guo's and Chen's results that *MI*'s highest annual volume increment occurred between 15 to 17 years after planting [26,35]. All of this might make us believe that *MI* could be an adaptive tree species in cities as it could play a better role as a carbon sink under the global change [45]. Furthermore, combined with its rapid and vigorous growth of volume, *MI* might attract more attention on the short- and long-term ecological and economic benefits [46,47].

It was reported that China has a high frequency of typhoons with a spatial peak in GBA every year [48,49]. The resistance of urban trees to breakage or overturning in windy climates largely relied on structural modifications to obtain mechanical strength, and the biomass allocation to the root system had a positive impact on tree stability [50]. Besides, as demonstrated by global warming and rapid urbanization in GBA [51,52], it was essential for urban trees to develop competitive root systems to cope with this trend [53]. Furthermore, Zhang et al. pointed out that sufficient development of fine root biomass could be crucial for urban trees to cope with extreme drought events as they would grow in vertical and horizontal directions to absorb water [21]. In our research, *MI* had way higher below-ground biomass of coarse and fine root than *Cf* and *Sp* (Table 3, Figure 3), which might help to guarantee its adaptation to the urban environment. On one hand, the greatest coarse root biomass of *MI* tended to be a site-specific advantage to avoid the overturning risk, and on the other hand, its largest fine root biomass might have the greatest possibilities of adapting to the local urban environment under a warmer background.

4.3. Impact on Soil Properties

Generally, soil physical properties acted as important soil quality indicators [54]. For the overall 0–100 cm soil layer, no significant differences were found between the three tree species. Nevertheless, our results showed that *Sp* had a lower FC and SMC than *Cf* which was in line with the result of Tian et al. that *Sp* would have more severe soil water loss than *Cf* [55]. Furthermore, the highest FC and SMC of *MI* among the three trees, suggesting that a higher water content in soils could help to explain why *MI* had a more prosperous development of below-ground biomass, as soil water would promote the distribution and growth of root system [56,57]. Cassel et al. also stated that a high water capacity usually meant that adequate water could be used by plants [58], which could contribute to alleviating drought stress [53]. As the soil is usually very dense and compact in cities [59], the capacity of holding water in soils could be a specific advantage of urban tree species in GBA to cope with potential water shortage under the global change.

For soil chemical properties, *Cf* had significantly higher TK and AK while significantly lower AN and AK were observed for *Sp* and *MI*, respectively. Contrary to the result of Selvalakshmi et al. that *Cf* had a decrease of TK in the natural forest [60], *Cf* was observed to increase the amount of K in soils than the other two tree species in our research, which could have resulted from the difference between the natural environment and urban area. Unlike the compact space in the natural forest, city trees usually did not encounter various interspecific competition therefore they could have adequate growth, especially the fine root growth [22,61], which probably changed the release patterns of TK

in soils [62]. *Sp* had less AN compared to *Ml* and *Cf*, which could be explained by its small range of ecosystem functions, providing a less diverse array of N-related substrates and nutrients to microbial communities, which was also proved by Wang et al. [63]. For TP and AP, no significant difference was found among the three tree species, which was probably due to the inactive nature of phosphorus, especially in acidic conditions [64]. This information could help to provide guidelines for city managers that, on one hand, fertilization should take the impact of species on soil properties into account to maximize the effect; on the other hand, it was better to launch soil measurements regarding soil nutrients before planting new trees in order to select more adaptive tree species.

5. Conclusions

It is predicted that global change combined with urbanization will impact increasingly on the society and terrestrial ecosystem in GBA. In our study, *Ml* had the greatest tree growth and total biomass, which was same as the patterns in natural forests, proving its well adaptation to the urban environment and strong capacity of fixing carbon. Besides, *Ml*'s higher root:shoot ratios, combined with great root biomass, suggested that it might cope better with the local environment in GBA, that its strong coarse root helped to reduce the overturning risk and vigorous fine root could alleviate drought stress. *Cf*, a tree species relying strongly on the quality of the growing environment, had a decreased growth of DBH and volume compared to natural forests, suggesting being negatively affected by the urban environment. However, *Cf* significantly increased TK and AK in the soil while *Sp* and *Ml* had a reduced AN and AK, respectively. This indicated that *Cf* could be considered to be planted in the areas lacking TK and AK to improve the soil quality. For *Sp*, it had a vigorous development in its fast-growing period while the growth of DBH was reduced between six and 12 years. However, it recovered the DBH increment after 12 years which probably suggested it needed to take a longer time than other tree species to adapt to urban environment.

Overall, different tree species may have different adaptation strategies to urban surroundings and their adaptation can be various and vary with time accordingly. Detailed and precise information on the growth patterns and ecosystem services are extremely necessary for the appropriate selection of urban trees, which will promote a better understanding of urban ecosystems.

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References

1. Angel, S.; Parent, J.; Civco, D.L.; Blei, A.; Potere, D. The dimensions of global urban expansion: Estimates and projections for all countries, 2000–2050. *Prog. Plan.* **2011**, *75*, 53–107. [[CrossRef](#)]
2. Seto, K.C.; Fragkias, M.; Güneralp, B.; Reilly, M.K. A meta-analysis of global urban land expansion. *PLoS ONE* **2011**, *6*, e23777. [[CrossRef](#)] [[PubMed](#)]
3. Breshears, D.D.; Cobb, N.S.; Rich, P.M.; Price, K.P.; Allen, C.D.; Balice, R.G.; Romme, W.H.; Kastens, J.H.; Floyd, M.L.; Belnap, J. Regional vegetation die-off in response to global-change-type drought. *Proc. Natl. Acad. Sci.* **2005**, *102*, 15144–15148. [[CrossRef](#)] [[PubMed](#)]
4. Alberti, M. The effects of urban patterns on ecosystem function. *Int. Reg. Sci. Rev.* **2005**, *28*, 168–192. [[CrossRef](#)]
5. Tyrväinen, L.; Pauleit, S.; Seeland, K.; de Vries, S. Benefits and uses of urban forests and trees. In *Urban Forests and Trees*; Springer: Berlin, Heidelberg, 2005; pp. 81–114.

6. Roy, S.; Byrne, J.; Pickering, C. A systematic quantitative review of urban tree benefits, costs, and assessment methods across cities in different climatic zones. *Urban For. Urban Green.* **2012**, *11*, 351–363. [[CrossRef](#)]
7. Zhang, C.; Stratopoulos, L.M.F.; Pretzsch, H.; Rötzer, T. How Do *Tilia cordata* Greenspire Trees Cope with Drought Stress Regarding Their Biomass Allocation and Ecosystem Services? *Forests* **2019**, *10*, 676. [[CrossRef](#)]
8. Arthur, T.; Martin, S. *Street Tree Directory*; Royal Australian Institute of Parks & Recreation: Minneapolis, MN, USA, 1981.
9. Miller, R.W.; Hauer, R.J.; Werner, L.P. *Urban Forestry: Planning and Managing Urban Greenspaces, USA*; Waveland Press: Illinois, CL, USA, 2015.
10. Low, N. *The Green City: Sustainable Homes, Sustainable Suburbs*; UNSW Press: Sydney, Australia, 2005.
11. Burden, D. *22 Benefits of Urban Street Trees*; Glatting Jackson, Walkable Communities, Inc.: High Springs, FL, USA, 2006.
12. Sutton, M.; Dragosits, U.; Theobald, M.; McDonald, A.; Nemitz, E.; Blyth, J.; Sneath, R.; Williams, A.; Hall, J.; Bealey, W. The role of trees in landscape planning to reduce the impacts of atmospheric ammonia deposition. In Proceedings of the Twelfth Annual IALE (UK) Conference, Cirencester, UK, 21–24 June 2004.
13. Nowak, D.J.; Crane, D.E. Carbon storage and sequestration by urban trees in the USA. *Environ. Pollut.* **2002**, *116*, 381–389. [[CrossRef](#)]
14. Grote, R.; Samson, R.; Alonso, R.; Amorim, J.H.; Cariñanos, P.; Churkina, G.; Fares, S.; Thiec, D.L.; Niinemets, Ü.; Mikkelsen, T.N. Functional traits of urban trees: Air pollution mitigation potential. *Front. Ecol. Environ.* **2016**, *14*, 543–550. [[CrossRef](#)]
15. Rahman, M.A.; Moser, A.; Rötzer, T.; Pauleit, S. Microclimatic differences and their influence on transpirational cooling of *Tilia cordata* in two contrasting street canyons in Munich, Germany. *Agric. For. Meteorol.* **2017**, *232*, 443–456. [[CrossRef](#)]
16. Gardiner, B.; Berry, P.; Moulia, B. Wind impacts on plant growth, mechanics and damage. *Plant Sci.* **2016**, *245*, 94–118. [[CrossRef](#)] [[PubMed](#)]
17. Day, S.D.; Wiseman, P.E.; Dickinson, S.B.; Harris, J.R. Contemporary concepts of root system architecture of urban trees. *Arboric. Urban For.* **2010**, *36*, 149–159.
18. Grabosky, J.; Bassuk, N. A new urban tree soil to safely increase rooting volumes under sidewalks. *J. Arboric.* **1995**, *21*, 187.
19. Mullaney, J.; Lucke, T.; Trueman, S.J. The effect of permeable pavements with an underlying base layer on the growth and nutrient status of urban trees. *Urban For. Urban Green.* **2015**, *14*, 19–29. [[CrossRef](#)]
20. Morgenroth, J.; Buchan, G.D. Soil moisture and aeration beneath pervious and impervious pavements. *J. Arboric.* **2009**, *35*, 135.
21. Zhang, C.; Stratopoulos, L.M.F.; Xu, C.; Pretzsch, H.; Rötzer, T. Development of Fine Root Biomass of Two Contrasting Urban Tree Cultivars in Response to Drought Stress. *Forests* **2020**, *11*, 108. [[CrossRef](#)]
22. Pretzsch, H.; Biber, P.; Uhl, E.; Dahlhausen, J.; Schütze, G.; Perkins, D.; Rötzer, T.; Caldentey, J.; Koike, T.; van Con, T. Climate change accelerates growth of urban trees in metropolises worldwide. *Sci. Rep.* **2017**, *7*, 15403. [[CrossRef](#)]
23. Tubby, K.; Webber, J. Pests and diseases threatening urban trees under a changing climate. *For. Int. J. For. Res.* **2010**, *83*, 451–459. [[CrossRef](#)]
24. Fang, J. Ecological Greenway Construction in Shunde District, Foshan City. *J. Anhui Agric. Sci.* **2011**, *2011*, 161.
25. Chuanguo, L.J.F.Z.C.; Hongyue, K.M.C. Investigation of Tree Species Composition of Fengshui Woods in Foshan City. *Guangdong For. Sci. Technol.* **2006**, *1*, 39–43.
26. Chaohui, Z.; Jieming, L.; Huiqing, L. The problems and countermeasures of urban greening construction in Foshan. *Guangdong For. Sci. Technol.* **2014**, *36*, 57–61.
27. Chen, L.; Zeng, J.; Jia, H.-Y.; Zeng, J.; Guo, W.-F.; Cai, D.-X. Growth and nutrient uptake dynamics of *Mytilaria laosensis* seedlings under exponential and conventional fertilizations. *Soil Sci. Plant Nutr.* **2012**, *58*, 618–626. [[CrossRef](#)]
28. Lin, S.; Iqbal, J.; Hu, R.; Feng, M. N₂O emissions from different land uses in mid-subtropical China. *Agric. Ecosyst. Environ.* **2010**, *136*, 40–48. [[CrossRef](#)]
29. Li, Y.Y.; Shao, M.A. Change of soil physical properties under long-term natural vegetation restoration in the Loess Plateau of China. *J. Arid Environ.* **2006**, *64*, 77–96. [[CrossRef](#)]

30. Liu, G.; Jiang, N.; Zhang, L.; Liu, Z. *Soil Physical and Chemical Analysis and Description of Soil Profiles*; China Standard Methods Press: Beijing China, 1996; Volume 24, p. 266.
31. Lappi, J. Calibration of height and volume equations with random parameters. *For. Sci.* **1991**, *37*, 781–801.
32. Yao, W.; Krzystek, P.; Heurich, M. Tree species classification and estimation of stem volume and DBH based on single tree extraction by exploiting airborne full-waveform LiDAR data. *Remote Sens. Environ.* **2012**, *123*, 368–380. [[CrossRef](#)]
33. Wang, X.; Fang, J.; Tang, Z.; Zhu, B. Climatic control of primary forest structure and DBH–height allometry in Northeast China. *For. Ecol. Manag.* **2006**, *234*, 264–274. [[CrossRef](#)]
34. Team, R.C. *R: A Language and Environment for Statistical Computing*; R Foundation for Statistical Computing: Vienna, Austria, 2013.
35. Da Silva, R.P.; dos Santos, J.; Tribuzy, E.S.; Chambers, J.Q.; Nakamura, S.; Higuchi, N. Diameter increment and growth patterns for individual tree growing in Central Amazon, Brazil. *For. Ecol. Manag.* **2002**, *166*, 295–301. [[CrossRef](#)]
36. Vihervaara, P.; Marjokorpi, A.; Kumpula, T.; Walls, M.; Kamppinen, M. Ecosystem services of fast-growing tree plantations: A case study on integrating social valuations with land-use changes in Uruguay. *For. Policy Econ.* **2012**, *14*, 58–68. [[CrossRef](#)]
37. Guo, W.F.; Cai, D.X.; Jia, H.Y.; Li, Y.X.; Lu, Z.F. Growth laws of *Mytilaria laosensis* plantation. *For. Res.-Chin. Acad. For.* **2006**, *19*, 585.
38. Ming, A.; Jia, H.; Zhao, J.; Tao, Y.; Li, Y. Above-and below-ground carbon stocks in an indigenous tree (*Mytilaria laosensis*) plantation chronosequence in subtropical China. *PLoS ONE* **2014**, *9*, e109730. [[CrossRef](#)]
39. Zhang, X.; Duan, A.; Zhang, J. Tree biomass estimation of Chinese fir (*Cunninghamia lanceolata*) based on Bayesian method. *PLoS ONE* **2013**, *8*, 1–7. [[CrossRef](#)]
40. Zheng, Y.; Zhu, H.; Xu, H.; Xu, F. The characteristics of growing processes of Chinese fir and division of its growth stages. *J. Zhejiang For. Coll.* **1991**, *8*, 219–226.
41. Zhao, D.; Kane, M. Differences in growth dynamics of loblolly and slash pine plantations in the southeastern United States. *For. Ecol. Manag.* **2012**, *281*, 84–92. [[CrossRef](#)]
42. Chmura, D.J.; Rahman, M.S.; Tjoelker, M.G. Crown structure and biomass allocation patterns modulate aboveground productivity in young loblolly pine and slash pine. *For. Ecol. Manag.* **2007**, *243*, 219–230. [[CrossRef](#)]
43. Howard, J. Climate change mitigation and adaptation in developed nations: A critical perspective on the adaptation turn in urban climate planning. In *Planning for Climate Change*; Routledge: London, UK, 2009; pp. 43–56.
44. Poorter, H.; Nagel, O. The role of biomass allocation in the growth response of plants to different levels of light, CO₂, nutrients and water: A quantitative review. *Funct. Plant Biol.* **2000**, *27*, 1191. [[CrossRef](#)]
45. Myeong, S.; Nowak, D.J.; Duggin, M.J. A temporal analysis of urban forest carbon storage using remote sensing. *Remote Sens. Environ.* **2006**, *101*, 277–282. [[CrossRef](#)]
46. Larocque, G.; DesRochers, A.; Larchevêque, M.; Tremblay, F.; Beaulieu, J.; Mosseler, A.; Major, J.; Gaussiran, S.; Thomas, B.; Sidders, D. Research on hybrid poplars and willow species for fast-growing tree plantations: Its importance for growth and yield, silviculture, policy-making and commercial applications. *For. Chron.* **2013**, *89*, 32–41. [[CrossRef](#)]
47. Siregar, U.J.; Rachmi, A.; Massijaya, M.; Ishibashi, N.; Ando, K. Economic analysis of sengon (*Paraserianthes falcata*) community forest plantation, a fast growing species in East Java, Indonesia. *For. Policy Econ.* **2007**, *9*, 822–829. [[CrossRef](#)]
48. Huang, X.; Yan, L.; Wang, S.; Cheng, Z. Analysis of the characteristics of tornados in Foshan City and their circulation background. *Guangdong Meteor* **2014**, *36*, 20–24.
49. Fan, W.; Yu, X. Characteristics of spatial-temporal distribution of tornadoes in China. *Meteor. Mon.* **2015**, *41*, 793–805.
50. Nicoll, B.C.; Ray, D. Adaptive growth of tree root systems in response to wind action and site conditions. *Tree Physiol.* **1996**, *16*, 891–898. [[CrossRef](#)]
51. Francesch-Huidobro, M.; Mai, Q. Climate advocacy coalitions in Guangdong, China. *Adm. Soc.* **2012**, *44*, 43S–64S. [[CrossRef](#)]
52. Zhang, H.Q.; Luo, J.M.; Xiao, Q.; Guillet, B.D. The impact of urbanization on hotel development: Evidence from Guangdong Province in China. *Int. J. Hosp. Manag.* **2013**, *34*, 92–98. [[CrossRef](#)]

53. Stratópoulos, L.M.F.; Zhang, C.; Häberle, K.-H.; Pauleit, S.; Duthweiler, S.; Pretzsch, H.; Rötzer, T. Effects of Drought on the Phenology, Growth, and Morphological Development of Three Urban Tree Species and Cultivars. *Sustainability* **2019**, *11*, 5117. [[CrossRef](#)]
54. Boix-Fayos, C.; Calvo-Cases, A.; Imeson, A.; Soriano-Soto, M. Influence of soil properties on the aggregation of some Mediterranean soils and the use of aggregate size and stability as land degradation indicators. *Catena* **2001**, *44*, 47–67. [[CrossRef](#)]
55. Tian, Y.; Li, X.; Yuan, Z.; He, Y.; Chen, X.; Ni, A. Studies on benefit of soil and water conservation of different forest types in red soil regions of South Hunan. *Res. Soil Water Conserv.* **2002**, *9*, 80–82.
56. Corcobado, T.; Cubera, E.; Moreno, G.; Solla, A. Quercus ilex forests are influenced by annual variations in water table, soil water deficit and fine root loss caused by Phytophthora cinnamomi. *Agric. For. Meteorol.* **2013**, *169*, 92–99. [[CrossRef](#)]
57. Schenk, H.J.; Jackson, R.B. Mapping the global distribution of deep roots in relation to climate and soil characteristics. *Geoderma* **2005**, *126*, 129–140. [[CrossRef](#)]
58. Cassel, D.; Nielsen, D. Field capacity and available water capacity. *Methods Soil Anal.* **1986**, *5*, 901–926.
59. Day, S.; Bassuk, N.; Van Es, H. Effects of four compaction remediation methods for landscape trees on soil aeration, mechanical impedance and tree establishment. *J. Environ. Hortic.* **1995**, *13*, 64–71.
60. Selvalakshmi, S.; Vasu, D.; Zhijun, H.; Guo, F.; Ma, X. Soil nutrients dynamics in broadleaved forest and Chinese fir plantations in subtropical forests. *J. Trop. For. Sci.* **2018**, *30*, 242–251.
61. Moser, A.; Rahman, M.A.; Pretzsch, H.; Pauleit, S.; Rötzer, T. Inter-and intraannual growth patterns of urban small-leaved lime (*Tilia cordata* mill.) at two public squares with contrasting microclimatic conditions. *Int. J. Biometeorol.* **2017**, *61*, 1095–1107. [[CrossRef](#)]
62. Jia, Y.-b.; Yang, X.-e.; Feng, Y.; Jilani, G. Differential response of root morphology to potassium deficient stress among rice genotypes varying in potassium efficiency. *J. Zhejiang Univ. Sci. B* **2008**, *9*, 427. [[CrossRef](#)]
63. Wang, Y.; Zheng, H.; Chen, F.; Yang, Y.; Zeng, J.; Van Nostrand, J.D.; Zhou, J.; Ouyang, Z. Artificial reforestation produces less diverse soil nitrogen-cycling genes than natural restoration. *Ecosphere* **2019**, *10*, e02562. [[CrossRef](#)]
64. Li, Z.; Fang, W.; Lu, D. Physical and chemical properties of soils in Heshan hilly land. *Acta Ecol. Sin.* **1995**, *15*, 93–102.

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