Growth of Palm Trees and Woods in the Urban Environment

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Abstract

Trees in the urban environment provide several ecosystem benefits to the population, such as decreasing temperature, increasing humidity, shading, improving air quality, as well as physical and mental well-being. These can be enhanced through the knowledge of the growth of the trees in function of the characteristics of the place where they are inserted. Thus, the objective was to estimate the growth in diameter, height and volume of forest species in the urban environment, in Viçosa, Minas Gerais, Brazil. For this, woody individuals and palm trees present in the urban afforestation of the headquarters campus of the Federal University of Viçosa were selected based on age and had their diameter, breast height and height measured. Allometric equations specific to the study site were used to estimate their volume, and through the relationship with age, the average annual increment was obtained. Woody individuals showed a growth rate in volume of 0,0279 ± 0,0274 m³ year-1 and palm trees, 0,0139 ± 0,0119 m³ year-1. The differences in the average annual increase in volume found between woody individuals and palm trees may be due to morphological differences that affect the secondary growth of individuals. The growth rate of trees in the urban environment is higher when compared to those in forest fragments and experimental plantings. The decrease in growth rates with increasing age was expected due to the relationship between them being of the non-linear type, following a sigmoidal model.

Introduction

The use of trees and palms to compose urban afforestation provides a healthier physical environment for the population (ROSSATTO; TSUBOY; FREI, 2008). Improving the quality of the local microclimate with decreasing temperature; elevation of humidity; environmental preservation; attraction of avifauna; reduction of noise and visual pollution levels; natural barrier against winds; revaluation of contemporary spaces; scenic beauty and physical and mental well-being to the population are benefits of urban afforestation (GENGO; HENKES, 2013). Thus, afforestation d this environment is also responsible for improving adverse conditions, ensuring better housing in cities (LACY; SHACKLETON, 2014).

These benefits depend on the abundance, size and growth of individuals and, in order to potentiate them, it is necessary to improve the understanding of how trees develop in the urban environment, which is still a gap, especially for native species (LACY; SHACKLETON, 2014; EVANS et al., 2017). This information is relevant also to the appropriate selection of species, choice of location of planting, spacing the plants, distances relative to other urban components, direction for shading, and necessary silvicultural practices (Semenzato; CATTANEO; DAINESE 2011; PRETZSCH et al., 2015).

The growth rates of urban trees and palms vary depending on the species, local climatic condition, volume, porosity and soil chemistry, canopy irradiance and air quality (IAKOVOGLOU et al., 2001; MORGENROTH; BUCHAN; SCHARENBROCH, 2013; BOUKILI et al., 2017; FIGUEIREDO FILHO et al., 2017). Paving the soil surface is a limiting factor for growth due to compaction and adverse conditions generated, such as reduced aeration, low water infiltration and less accumulation of organic matter (VISWANATHAN et al., 2011; LAWRENCE et al., 2012). Allied to this, the planting conditions, management

strategies adopted, such as irrigation and pruning, and the people who benefit from urban trees also influence growth and, thus, there may be differences within and between locations (SEMENZATO; CATTANEO; DAINESE, 2011; VOGT et al., 2015) . Understanding the annual rates at which trees and palms grow in the urban environment is essential to support correct estimates of the provision of ecosystem services over time, despite this, few studies have made these estimates (VAZ MONTEIRO; LEVANIČ; DOICK, 2017). Thus, the aim of this study was to investigate the growth of different species of palm and woody species in the urban environment, in Viçosa, Minas Gerais, Brazil. The hypotheses analyzed were that i) palm and woody species show different growth rates; ii) the growth rate differs, within each previous group, depending on the species, and iii) native species show a higher growth rate than exotic species.

Methods

The forest, palm and woody species present in the access roads, parking lots and lawns on the *campus* of the Federal University of Viçosa in Viçosa, Minas Gerais, Brazil (20°45'14" S and 42°45'53" W) were evaluated. The region's vegetation is classified as Montana seasonal semideciduous forest (IBGE, 2012), with Cwa climate (Köppen) and concentrated rainfall between the months of October and March. On average, the average daily maximum and minimum temperature and annual precipitation were 27.2°C, 16°C and 1184.9 mm, respectively (UFV, 2018).

The selection of the studied species was based on the knowledge of the age of the individuals, this being the first stage of the research. The age was estimated through orthophotocards from the city of Viçosa, available in the collection of the Department of Forestry at UFV, historical records of the institution and also with images of *Google Earth Pro* [®].

The age (I*nd*) attributed to the individuals identified in the images was obtained by I*nd* = 2018 - (AP + AA) / 2, being AP: year of the orthophoto/image where the individual was identified and; AA: year of the orthophotocarte/image immediately preceding it. The conversion was necessary since, it is not known exactly when, between the two images (AP and AA), the individual was planting, thus adopting the average age of the period.

Individuals whose age was estimated and had more than 5 centimeters in diameter at chest height (DBH), were inventoried between April and May 2018. The total height (Ht), in meters, was measured with a Vertex Laser 5 Hypsometer and the Circumference at Chest Height (CAP), in centimeters, obtained with a measuring tape and converted to DAP by the expression DAP = CAP / π. The botanical identification was carried out with the collection of vegetative material for analysis in the UFV Dendrology sector .

Volumetric equations of Shumacher and Hall were adjusted based on rigorous cubing data performed in the same study site in 2010. The volume of palm and woody individuals was obtained, respectively, by $V_i = 0.00006067 * (DBH_i)^{1.953} * (Ht_i)^{1.006}$ (R^2 = 99.17%) and $V_i = 0.0005425 * (DBH_i)^{1.6152524} * (Ht_i)^{0.7395611}$ (R^2 = 79.40%), where V_i: o volume of the *i- th* individual, in m³; DBH_i: diameter at chest height of

the i-th individual, in centimeters e; Ht_i: total height of the i-th individual, in meters (Brianezi et $al.,$ 2013 - adapted) .

The growth of individuals was estimated with the Average Annual Volume Increase (IMA_V - m³ year $^{-1}$), obtained by $IMA_{Vi} = V_i / I_{Indi}$, with IMA_{Vi}: the average annual increase in volume of the i-th individual, in m³ year $^{-1}$; V_i: the volume of the i-th individual, in m³, e; I_{Indi}: the age of the i-th individual, in years . The Annual Average Increment in Diameter and Height, IMA_D (cm year $^{-1}$) and IMA_H (m year $^{-1}$), respectively, were obtained through the ratio between the value obtained in the forest inventory and the individual's age.

The average increments in volume, diameter and height according to the origin of the species, native to the Atlantic Forest, native to Brazil or exotic, were analyzed with ANOVA in a completely randomized design. The Tukey test was applied when there was a rejection of the null hypothesis. The analyzes of variance and comparisons between the averages were performed with confidence intervals with 99% certainty. The statistical procedures were performed $using$ the R $software.$

Results

Through the forest inventory, 1,888 individuals were evaluated, 86.97 % belonging to the woody group. $Licania$ $tomentosa$, $Michelia$ $champaca$ and $Archontophoenix$ $alexandrae$ were the species with the largest number of individuals (Table 1). $Michelia$ $champaca$, $Delonix$ $regia$ and $Archontophoenix$ $alexandrae$, on average, presented the oldest individuals with 93 years, 60 years and 53.8 years, respectively (Table 1).

Table 1. Number of individuals (Ind), average DBH (DBHm, in cm), average height (Htm, in m) and average volume (Vm, in m³), by age range (I, in years), of the species evaluated in Viçosa, Minas Gerais, Brazil, in 2018

Species	I	Ind	DBH_m	Ht_m	V_m
Woody					
Albizia lebbeck (L.) Benth.	20 - 40	3	40.98	17.4	1.9127
Anadenanthera macrocarpa (Benth.) Brenan	20 - 40	6	54.22	26.9	4.2408
Araucaria columnaris (JR Forst.) Hook.	20 - 40	3	40.26	13.9	1.7147
Bauhinia forficata Link	20 - 40	140	27.17	8.5	0.6652
Bombacopsis glabra (Pasq.) A. Robyns	20 - 40	4	30.25	11.2	0.9984
Bougainvillea glabra Choisy	20 - 40	15	11.19	6.9	0.1809
Delonix regia (Bojer ex Hook.) Raf.	60 - 80	44	80.84	11.8	4.3474
Filicium decipiens (Wight & Arn.) Thwaites	0 - 20	40	15.39	9.0	0.3864
	20 - 40	28	14.96	7.5	0.3041
Handroanthus impetiginosus (Mart. ex DC.) Mattos	20 - 40	62	26.26	16.1	1.1514
	40 - 60	3	37.27	21.4	2.1352
Handroanthus serratifolius (Vahl) S. Grose	20 - 40				
		57	18.32	11.4	0.5041
Hibiscus rosa-sinensis L.	40 - 60	12	34.70	15.8	1.4581
Holocalyx balansae Micheli	20 - 40	9	17.07	6.4	0.2311
Lagerstroemia indica L.	20 - 40	6	30.68	14.6	1.2823
	0 - 20	25	9.28	6.4	0.0941
	20 - 40	72	12.82	7.3	0.1852
Lagerstroemia speciosa (L.) Pers.	40 - 60	19	24.93	7.3	0.5054
	0 - 20	28	16.81	9.1	0.4151
Licania tomentosa (Benth.) Fritsch	20 - 40	16	33.80	12.9	1.3051
	0 - 20	41	14.06	7.7	0.2667
	20 - 40	281	31.92	12.0	1.0751
Ligustrum lucidum W.T.Aiton	40 - 60	104	36.54	14.0	1.4348
	20 - 40	9	39.81	11.0	1.3410
Litchi chinensis Sonn.	40 - 60	9	36.27	9.9	1.0856
Mangifera indica L.	20 - 40	3	33.51	9.8	1.4619

Michelia champaca L.	20 - 40	6	24.33	10.6	1.9185
Murraya paniculata (L.) Jack	80 - 100	192	33.37	7.2	0.7157
	0 - 20	23	10.08	3.8	0.0808
	20 - 40	60	11.91	4.0	0.1188
Paubrasilia echinata (Lam.) Gagnon, H.C. Lima & G.P. Lewis	40 - 60	33	11.30	4.1	0.0931
Peltophorum dubium (Spreng.) Taub.	20 - 40	14	12.93	8.0	0.2589
Poincianella pluviosa (DC.) L.P. Queiroz	20 - 40	7	33.68	12.4	1.2668
	0 - 20	8	18.89	8.5	0.3941
Spathodea campanulata P. Beauv.	20 - 40	76	30.85	13.6	1.3527
Tabebuia roseoalba (Ridl.) Sandwith	40 - 60	70	55.34	13.4	2.8216
Terminalia catappa L.	20 - 40	3	37.35	9.8	1.0862
Tibouchina granulosa (Desr.) Cogn	20 - 40	39	28.62	11.2	0.9492
	0 - 20	12	10.97	6.2	0.1754
Palm Trees					
Acrocomia aculeata (Jacq.) Lodd. ex Mart.	20 - 40	5	33.99	14.8	0.8924
Archontophoenix alexandrae (F. Muell.) H. Wendl. e Drude	0 - 20	12	20.52	11.2	0.2622
	20 - 40	12	21.62	11.2	0.2945
	40 - 60	27	24.02	14.1	0.4797
	60 -80	136	23.40	15.1	0.4738
Syagrus romanzoffiana (Cham.) Glassman	0 - 20	32	24.40	9.6	0.3979
	20 - 40	17	25.17	10.4	0.3735
	40 - 60	5	30.23	19.2	0.9793

Woody individuals presented an average annual increase in volume higher than that of palm trees, 0.02 79 ± 0.02 74 and 0.0 139 ± 0.0 119 m³ year -1 respectively (Table 2). The same behavior was observed for the increase in diameter, however in height, the individuals of palm trees showed the highest average annual increase (Table 2). Individually, *Anadenanthera macrocarpa* and *Mangifera indica* presented the highest values of IMAv, 0.1588 ± 0.0504 m³ year^{-1} and 0.0959 ± 0.0584 m³ year^{-1}, respectively, followed by the palm tree *Acrocomia columnaris* which presented equal IMAv at 0.0446 ± 0.0056 m³ year^{-1} (Table 2).

Table 2. Average annual increment in Volume (IMAv, in m³), Diameter (IMAD, in cm) and Height (IMAH, in m) and standard deviation (s_1, s_2 and s_3, respectively) of the species studied in Viçosa, Minas Gerais, Brazil, in 2018

Species	IMA$_V$	s_1	IMA$_D$	s_2	IMA$_H$	s_3
Woody	0.0279	0.0274	1.0130	0.5155	0.3780	0.2522
Albizia lebbeck	0.0696	0.0181	1.5379	0.1540	0.6315	0.1306
Anadenanthera macrocarpa	0.1588	0.0504	2.1251	0.2372	1.0181	0.1189
Araucaria columnaris	0.0784	0.0180	2.0059	0.2542	0.6433	0.2401
Bauhinia forficata	0.0242	0.0120	1.0637	0.2931	0.3090	0.0594
Bombacopsis glabra	0.0363	0.0128	1.2440	0.1684	0.4073	0.0766
Bougainvillea glabra	0.0066	0.0048	0.6222	0.3334	0.4097	0.2217
Delonix regia	0.0725	0.0280	1.3838	0.2650	0.1968	0.0403
Filicium decipiens	0.0253	0.0178	1.4377	0.6570	0.6503	0.3276
Handroanthus impetiginosus	0.0419	0.0276	1.0438	0.3777	0.5791	0.2208
Handroanthus serratifolius	0.0201	0.0161	0.7153	0.2852	0.3967	0.1504
Hibiscus rosa-sinensis	0.0088	0.0038	0.6769	0.1528	0.2443	0.0684
Holocalyx balansae	0.0466	0.0250	1.2484	0.3773	0.5303	0.1007
Lagerstroemia indica	0.0086	0.0041	0.7514	0.2449	0.3743	0.1426
Lagrestroemia speciosa	0.0470	0.0273	1.8910	0.4323	0.7480	0.2081
Licania tomentosa	0.0317	0.0151	1.0640	0.3437	0.3957	0.1534
Ligustrum lucidum	0.0445	0.0262	1.5477	0.6049	0.4067	0.1533
Litchi chinensis	0.0532	0.0131	2.3080	1.3011	0.7830	0.7153
Mangifera indica	0.0959	0.0584	3.3934	1.1623	1.7317	1.0115
Michelia champaca	0.0077	0.0038	0.5012	0.1223	0.1070	0.0337
Murraya paniculata	0.0048	0.0039	0.6520	0.3555	0.2183	0.1353
Paubrasilia echinata	0.0120	0.0106	0.7364	0.2885	0.3768	0.1533
Peltophorum dubium	0.0461	0.0276	1.3078	0.4247	0.4514	0.1152
Poincianella pluviosa	0.0522	0.0460	1.4416	0.5167	0.6131	0.3296
Spathodea campanulata	0.0571	0.0341	1.1748	0.3063	0.2753	0.0730
Tabebuia roseoalba	0.0395	0.0157	1.3952	0.2912	0.3552	0.0615
Terminalia catappa	0.0388	0.0252	1.2771	0.4374	0.4664	0.1759
Tibouchina granulosa	0.0114	0.0099	0.8326	0.5349	0.3768	0.2217

Palm tree	0.0139	0.0119	0.8457	0.7313	0.4022	0.2426
Acrocomia aculeata	0.0446	0.0056	1.6995	0.1055	0.7380	0.0478
Archontophoenix alexandrae	0.0089	0.0040	0.5148	0.2581	0.3066	0.1396
Syagrus romanzoffiana	0.0283	0.0146	1.9129	0.7889	0.7021	0.2626

The native woody species from Brazil and the Atlantic Forest showed greater increments in relation to volume, diameter and height compared to exotic species (Table 3). The condition was also observed for the palm species, where the native ones of the Atlantic Forest surpassed the exotic ones (Table 3).

Table 3 . Average annual increase in volume (IMAv , in m³), Diameter (IMAD , in cm) and Height (IMAH , in m) and standard deviation (s_1, s_2 and s_3, respectively) according to the origin of the species studied in Viçosa, Minas Gerais, Brazil, in 2018

Group	Origin	IMAV	s_1	IMAD	s_2	IMAH	s_3
Woody	Exotic	0.0240 b	0.0291	0.9641 b	0.6108	0.3264 c	0.2933
	Native Brazil	0.0360 a	0.0454	1.1596 a	0.6155	0.5115 a	0.3103
	Native Atlantic forest	0.0299 a	0.0176	1.0266 a	0.3537	0.3973 b	0.1625
Palm Trees	Exotic	0.0089 a	0.0040	0.5148 b	0.2581	0.3066 b	0.1396
	Native Atlantic forest	0.0297 a	0.0147	1.8948 a	0.7570	0.7051 a	0.2515

Means followed by the same letter in the column do not differ by Tukey 's test (P <0.01).

The woody species showed the largest increases in volume, diameter and height in individuals aged between 20 and 40 years, and the palm group , up to the age of 20 , but maintaining growth beyond those ages (Chart 1). The wide variation for each age group is associated with the diversity of species in each group.

Discussion

The ecosystem services provided by urban afforestation depend on the size and health of trees and palms, which in these places can be negatively or positively affected by biotic, abiotic, climatic and anthropogenic factors (VAZ MONTEIRO; LEVANIČ; DOICK, 2017). The results of this study show that the growth in diameter, height and volume varies m according to the type of the studied plant, monocot or

Eudicotiledonea with the origin of these species native of the Atlantic, Brazil or exotic and with age of individuals.

The woody plants and palm features ra m different growth rates 0.0279 ± 0.0274 and 0.0139 ± 0.0119 m³ ind^{-1}year^{-1}, respectively, mainly due to morphological differences that alter growth secondary education of individuals. In eudicotyledons, a group of woody species, secondary growth is characterized by the production of secondary xylem and the development of new protective tissues from the exchange rate (OLIVEIRA, 2011). In contrast, monocotyledons, such as palm trees, show an increase in stem diameter due to the division of fundamental tissues, these being primary growth structures (BOTÂNICO; ANGYALOSSY, 2013), which often limits the size of individuals compared to trees. Among tree species, the greatest increase in *Anadenanthera macrocarpa* may have occurred due to the adaptation of the species to adverse environmental conditions, with tolerance to shallow, compacted and even poorly drained soils (GONÇALVES et al., 2008). *Murraya paniculata* was the woody species with the lowest growth because it is a shrub (CHOWDHURY; BHUIYAN; YUSUF, 2008) with smaller size in diameter and height among all the analyzed species. Among the palm trees, the difference in the average increase in volume is due to the characteristic size of the species studied.

The average annual volumetric increase of woody species in the urban environment, 0.0279 ± 0.0274 m³ ind^{-1} year^{-1}, is higher than that found for *Araucaria angustifolia*, in two phytographic regions of Rio Grande do Sul, where there is a natural occurrence of the species with a maximum IMAv of 0.0198 m³ and 0.026 m³ (HESS; SCHNEIDER, 2010). In comparison with these data, the average growth of woody species in the urban area was lower than only a third fragment, which presented an average IMAv equal to 0.031 m³ year^{-1} (HESS; SCHNEIDER, 2010). In planting at the Embrapa Experimental Field in the Western Amazon, an IMAv of 0.039 m³ ind^{-1} year^{-1} was estimated for the species *Sclerolobium paniculata* and between 0.019 m³ ind^{-1} year^{-1} and 0.004 m³ ind^{-1} year^{-1} for *Hymenae courbaril*, *Carapa guianensis*, *Bertholettia excelsa*, *Swietenia macrophylla*, *Copaifera multijuga*, *Cedrela odorata*, *Trattinickia burseraefolia* and *Dipteryx odorota* (SOUZA et al., 2008). The volumetric growth of the studied species is greater in the urban environment than in forest fragments or plantations, which may be due to the absence or little competition. The lower density of trees in an area urban reduces the competition for light and other resources, thus fostering growth (McHALE et al., 2009), and consequently the provision of ecosystem services. Higher tree growth rates in the urban environment are also related to the climate in these locations, characterized by the effect of the heat island that causes higher temperatures in cities and can stimulate photosynthetic activity and extend the plant's growing season (PRETZSCH et al., 2017). It is important to note that the growth rate of trees and palms in the urban environment that are larger than in forest fragments also implies a faster aging of these individuals, thus indicating the need for their replacement and replanting (PRETZSCH et al., 2017). The existing variation also indicates the need to take into account the growth in the choice of species to compose urban afforestation.

Species of palm trees and woody native Atlantic Forest to and naturally occurring in Brazil showed higher average growth rates in diameter, height, and therefore volume. Native species also showed growth rates

higher than the Exotic to s ex post when the s at the same level of light, for example, in Connecticut, USA (MARTIN; KOBE, 2010). And exotic species may have shown lower values as a result of adverse environmental conditions, even with some plasticity for adaptation (MUÑOZ et al., 2015; MARTIN; CANHAM; KOBE, 2010). The temperature and precipitation significantly influence the growth of the trees (VITALI; BÜNTGEN; BAUHUS, 2018), and variations between the place of origin of the species can contribute to the reduction of the increase rates. These factors even affect the species' vitality (WILLIAMS et al., 2012), and can cause individuals to become senescent at an early stage. Climate change has altered the frequency of extreme events and this will continue to alter the growth of species, including native species, and it is important to include these effects in growth projections (ZIMMERMANN et al., 2009).

The groups of plants studied, palm and woody, showed variation in growth according to age, being for the first group, the highest rates in individuals up to 20 years old, and for the second, those between 20 and 40 years old. This variation stems from the fact that the relationship between diameter / height and age are non-linear and, in the juvenile stage, growth occurs at a faster rate (VAZ MONTEIRO; LEVANIČ; DOICK, 2017). The increase in tree dimensions with increasing age causes these individuals to reach stages with limited availability of growth factors, light, water and nutrients, which explains the growth patterns in sigmoidal form (KÖHL; NEUPARE; LOTFIOMRAN, 2017). At advanced ages, even at lower rates compared to the juvenile stage, urban trees and palms continue to grow, which has implications for the provision of ecosystem services and also for the need for management of individuals.

The ecosystem services provided by trees and palms in the urban environment are influenced by different factors, such as age, size, spacing, free area. The interception of rainwater, for example, varies according to the species and size of the individuals, with those with PAD close to 3.5 cm intercepting about 15.3%, while those with 38.1 cm of DAP, can intercept up to 66.5% (XIAO; McPHESON, 2002). Larger trees also tend to remove and store more carbon dioxide, in addition to retaining more airborne pollutants (GRATANI; VARONE, 2006). In Rome, trees with DBH ranging from 50-80 cm, tend to remove, on average, 72% more carbon dioxide than those with DBH between 20-50 cm (GRATANI; VARONE, 2006). Thus, the growth rates of trees are indicative of carbon neutralization, expansion of the occupied area above and below ground and, consequently, provision of many ecosystem services (PRETZSCH et al., 2017). Thus, the sustainable management of the population will trees in a city can help mitigate the negative impacts of climate change and maximize the benefits generated, using, for this, information on growth rates, dimensional changes that depend on the age and situation (RÖTZER et al., 2019).

Conclusions

The growth rate of woody and palm forest species in the urban environment varies according to the type of plant, the origin of the species and the age of each individual, being, in general, faster than in forest fragments. This behavior brings several benefits to the local microclimate, such as interception of rainwater, shading, removal of carbon dioxide and interception of particles suspended in the air. On the

other hand, this accelerated rhythm can anticipate the senescence of individuals causing the anticipation of their replacement.

The growth curves according to the age of the individuals is an important indicator of the spatialization, over time, of the provision of ecosystem services, since many are related to the supply of biomass in the trunk, or to the increase and renewal of leaves in the canopy. The growth of individuals being maintained, even at lower rates, with maturity, denotes their continued contribution to climate change.

Municipal afforestation plans must also enhance the inclusion of species naturally present in the region. These species have a higher growth rate than exotic species, establishing themselves more quickly in the area, in addition to being a form of *ex situ* conservation.

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