Urban forest management tools

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Abstract

Objective: Contextualize the use of Urban Forest management tools to promote quality of life by maximizing the environmental services that trees provide to city dwellers.

Methodology: To present the state of the art in the development of monitoring technologies based on spatial and terrestrial platforms for the management of the urban forest, through the application of methods, techniques and technologies for monitoring, control and automation of survey and mapping processes, with views to decision making.

Originality / Relevance: The production of this work is the presentation of different tools for urban forest management in an up-to-date manner, combining technological resources with the needs of public managers and, therefore, contributing to the quality of life of the urban population.

Results: Some tools gaining notoriety due to their advantages in capturing information, such as Unmanned Aerial Vehicles (UAVs). Remote sensing technologies have become mandatory tools in city management, urban and environmental planning. The analysis of vegetation in the urban area, distribution and classification carried out through the extraction of the NDVI (Normalized Difference Vegetation Index) is also used to characterize large areas and locate arboreal specimens with suspected deficiency in plant health. LiDAR sensors perform laser scanning, providing topographic and forest cover analyzes that make it possible to simultaneously map the terrain under the trees and its estimated height. Remote sensing and Geographic Information System (GIS) techniques are combined to map land use and land cover changes and assess the rate of urban expansion and vegetation loss. Other promising computational tools are Artificial Intelligence (AI) and machine learning that proposes to develop devices that simulate the human capacity to reason, perceive, make decisions and solve problems.

Social/Management Contributions: The use of management tools for the urban forest are administrative and more agile resources that can help managers in decision-making to build a more sustainable and inclusive city.

Keywords: Urban forest. Management. Information technology. Tools.

Ferramentas para gestão da floresta urbana

Resumo

Objetivo: Contextualizar o uso de ferramentas de gestão da Floresta Urbana para promoção da qualidade de vida maximizando os serviços ambientais que as árvores prestam para os citadinos.

Metodologia: Apresentar o estado da arte do desenvolvimento de tecnologias de monitoramento fundamentadas em plataformas espaciais e terrestres para a gestão da floresta urbana, por meio da aplicação de métodos, técnicas e tecnologias de monitoramento, controle e automação de processos de levantamento e mapeamento, com vistas à tomada de decisão.

Originalidade/Relevância: A relevância deste trabalho está na apresentação das diferentes ferramentas para gestão da floresta urbana de maneira atualizada, aliando os recursos tecnológicos às necessidades dos gestores públicos e, com isso, contribuindo para a qualidade de vida da população urbana.

Resultados: Algumas ferramentas vêm ganhando notoriedade em decorrência das suas vantagens em captarem informações, como os Veículos Aéreos Não Tripulados (VANTs). Tecnologias de sensoriamento remoto tem se tornado ferramentas obrigatórias na gestão de cidades, no planejamento urbano e ambiental. A análise da vegetação na área urbana, distribuição e classificação efetuada por meio da extração do NDVI (Normalized Difference Vegetation Index) também é utilizada para caracterizar grandes áreas e localizar exemplares arbóreos com suspeitas de deficiência na saúde vegetal. Os sensores LiDAR executam varredura a laser propiciando análises topográficas e da cobertura florestal que possibilitam mapear, simultaneamente, o terreno sob as árvores e a sua altura estimada. As técnicas de sensoriamento remoto e Sistema de Informação Geográfica (SIG) são combinadas para mapear o uso e mudanças na cobertura da terra e medir a taxa de expansão urbana e perda de vegetação. Outras ferramentas computacionais promissoras são a Inteligência Artificial (IA) e o aprendizado de máquinas que se propõe a elaborar dispositivos que simulem a capacidade humana de raciocinar, perceber, tomar decisões e resolver problemas.

Contribuições sociais / para a gestão: A utilização de ferramentas de gestão para a floresta urbana são recursos necessários e mais ágeis que podem auxiliar os gestores na tomada de decisão para a construção de uma cidade mais sustentável e inclusiva.

Palavras-chave: Floresta urbana. Gestão. Tecnologia de informação. Ferramentas.

Herramientas de gestión forestal urbana

Resumen

Objetivo: Contextualizar el uso de herramientas de manejo de bosques urbanos para promover la calidad de vida maximizando los servicios ambientales que los árboles brindan a los habitantes de las ciudades.

Metodología: Presentar el estado del arte en el desarrollo de tecnologías de monitoreo basadas en plataformas espaciales y terrestres para el manejo del bosque urbano, mediante la aplicación de métodos, técnicas y tecnologías para el monitoreo, control y automatización de procesos de levantamiento y mapeo, con vistas a la toma de decisiones.

Originalidad / Relevancia: La relevancia de este trabajo radica en la presentación de diferentes herramientas para el manejo forestal urbano de manera actualizada, combinando los recursos tecnológicos con las necesidades de los gestores públicos y, por tanto, contribuyendo a la calidad de vida de los población urbana.

Resultados: Algunas herramientas han ido ganando notoriedad por sus ventajas en la captura de información, como los vehículos aéreos no tripulados (UAV). Las tecnologías de teledetección se han convertido en herramientas obligatorias en la gestión de la ciudad, la planificación urbana y medioambiental. El análisis de vegetación en el área urbana, distribución y clasificación realizado a través de la extracción del NDVI (Índice de Vegetación de Diferencia Normalizada) también se utiliza para caracterizar grandes áreas y localizar ejemplares arbóreos con sospecha de deficiencia en sanidad vegetal. Los sensores LiDAR realizan un escaneo láser, proporcionando análisis topográficos y de cobertura forestal que permiten mapear simultáneamente el terreno debajo de los árboles y su altura estimada. Las técnicas de sensores remotos y sistemas de información geográfica (SIG) se combinan para mapear el uso del suelo y los cambios en la cobertura del suelo y medir la tasa de expansión urbana y pérdida de vegetación. Otras herramientas computacionales prometedoras son la Inteligencia Artificial (IA) y el aprendizaje automático que propone desarrollar dispositivos que simulen la capacidad humana para razonar, percibir, tomar decisiones y resolver problemas.

Contribuciones sociales / para la gestión: El uso de herramientas de gestión para el bosque urbano son recursos necesarios y más ágiles que pueden ayudar a los gestores en la toma de decisiones para la construcción de una ciudad más sostenible e inclusiva.

Palabras clave: Bosque urbano. Gestión. Tecnologías de la información. Herramientas.

Introduction

The urban forest corresponds of arboreal-shrubby vegetation that makes up the landscape in the city, is located in the public or private areas, and provides physiological, sociological, economic and esthetic benefits to society (Randrup et al., 2005; Biondi, 2015). Trees provide quality of life and offer countless benefits, whether for landscape beautification or contemplation, such as improving air quality, thermal comfort, preserving biodiversity, protecting watersheds and restoring physical and mental health (Amato-Lourenço et al., 2016; Tyrväinen 2019; Salbitano 2019). However, these benefits can be threatened by tree felling, which is common in rainy seasons, and by the expansion process of Brazilian cities that do not take into account urban forest planning, causing widespread damage such as the displacement of the original vegetation cover and those consisting of urban afforestation, parks, squares, flowerbeds, gardens, etc., which are crucial for the quality of life metropolitan areas and for the conservation of biodiversity. According to a study conducted by São Paulo City Hall (2017), about 30 % of the urban areas is covered by remnants of the biome Atlantic Forest and the heterogeneity of this vegetation, not only the composition of plant physiognomies, but also the spatial location, shows the process of loss and fragmentation of natural environments that occurred due to occupation and urban growth). According to Carbone (2014), there are several ways to quantify green in cities, and comparison of available data should be done with caution, as different indicators may express different facets of green. It is also important to mention that the minimum standard of 12m² for green space per inhabitant, disseminated by some researchers as a reference by some researchers, established by the United Nations (UN), the World Health Organization (WHO) and United Nations Food and Agriculture Organization (FAO), according to Cavalheiro and Del Picchia (1992), is not known by these institutions and is considered to refer only to the categories of neighborhoods, parks districts and sectoral parks, that is, public areas with opportunities for outdoor recreation (Harder et al., 2006). The Brazilian Society of Urban Afforestation (1996) proposed 15 m² as vegetation cover/inhabitant coverage. To be aware of urban afforestation in the city of São Paulo, Buckeridge (2015) used the vegetation cover index (ICV) data published by the city of São Paulo, which according to Nucci (2001), takes into account all vegetation areas, including tree canopy, and found that today, excluding areas influenced by surrounding forest remnants, the city of São Paulo has an estimated average of 0.6 trees per inhabitant, but with a heterogeneous distribution ranging from almost zero in Itaim Paulista (0.06 trees per inhabitant) to about two in Butantã. Thus, urban afforestation is more concentrated in higher income neighborhoods than in the suburbs and the poorest areas of the city. As a result, a large part of the population suffers from environmental inequality with low quality of life and health. If we also take into account the projections of the United Nations

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(2012), which state that the world population will grow by more than 2 billion people in the next 40 years, exceeding the limit of 9 billion inhabitants, of which more and more than 65 % will live in cities, it is necessary to consider how the management of urban forests will be carried out.

Silva et al. (2019) conducted the mapping of urban green areas (EVU – most vegetation-covered areas in an area larger than 625 m²) in São Paulo Metropolitan Area (RMSP), as well as analysis of the per capita ratio of such areas at the inner city scale, and found the dimension of the lack of EVU combined with a high population density, corresponding to 30 % of the analyzed area, where 76.44 % of the urban population lives. The distributional imbalance of vegetation affects urban environmental and life quality, since vegetation is one of the main variables considering environmental quality indicators (Ribeiro et al., 2017).

In a study on environmental justice in Vila Andrade district, which is the largest contrast in the city of São Paulo, where people and rich people live side by side, vegetation exists almost only in areas with high standards, which play an important landscape role and contribute to thermal comfort. In poor neighborhoods, which correspond to almost half of the population, vegetation is practically non-existent, making the neighborhoods even drier and not taking advantage of vegetation. There is a profound environmental injustice, as the most vulnerable lower income inhabitants are exposed to the problems arising from the lack of environmental quality (Morato & Machado, 2015).

This work aims to incorporate the tools of information and communication technologies (ICTs) to support the urban forest management to improve the quality of life in urban centers.

Management tools

In Brazil, most municipalities do not have reports about the urban forest, such as the number of individual trees, botanical identification of species and their location (Hamamura, 2020). This lack of information makes the management of urban reforestation extremely difficult, both for carrying out management, such as pruning, and for planning new planting opportunities. Methods used to conduct tree inventory, felling risk or conservation status diagnosis of forest fragments and green spaces involve field work by specialized teams that typically use paper sheets to collect data in the field. These tasks require time, team training and labor hiring costs (Instituto de Pesquisas Tecnológicas do Estado de São Paulo, 2020).

To speed up these processes, some tools have gained notoriety due to their advantages in information collection, such as Unmanned Aerial Vehicles (UAVs), described as any aircraft designed to operate without a pilot on board, called Remotely Piloted Aircraft System (RPAS) which have an embedded payload, such as GNSS/GPS positioning systems,

embedded payload, such as GNSS/GPS positioning systems, embedded cameras and sensors. Hassan et al. (2016) used UAV equipped with a high-resolution RGB to count trees in urban areas and identified them with an accuracy of 72 %. As well as Rezende et al. (2020) to calculate the crown cover index of square trees and estimate the crown height.

Remote sensing technologies are becoming mandatory tools in urban city management, urban and environmental planning. They are used as data sources for geological, environmental, agricultural, cartographic, forestry, urban, oceanographic studies and surveys, among others. Above all, remote sensing imagery has become one of the only affordable forms of environmental monitoring at local and global scales, due to the speed, efficiency periodicity and synoptic view that characterize it (Crósta, 1992). Hamamura (2020) used it to map tree species faster and cheaper than the inventory, by using high-resolution multispectral satellite images or even hyperspectral images. Landsat is the main satellite used in remote sensing to provide free imagery for environmental studies. Although they are medium spatial resolution-images, the Landsat series stands out for its history of scenes as they contribute to the temporal monitoring of the surface (Borges et al., 2019).

With the advancement of technology, it is now easier and cheaper conduct mapping and monitoring of urban forests using UAVs equipped with high precision sensors such as thermal infrared and Light Detection and Ranging (LiDAR).

Thermal infrared sensors display the temperature to provide precise environmental analysis that is used for specific interventions, especially in urban environments to prevent falling trees that disrupt daily life in cities. According to Wagner and Ullrich (2006) not only information about the georeferenced location and 3D images of trees are collected, but also data about physical characteristics, such as the type of leaves, flowers, fruits, and bark. This makes it possible to identify the specimen and species, target characteristics such as size, reflectivity, and litter orientation, and surfaces such as asphalt or gravel.

The analysis of vegetation in urban areas, distribution and classification through the extraction of Normalized Difference Vegetation Index (NDVI), proposed by Rouse et al. (1973), is used to characterize large areas, obtaining a global view of the region and from there locate specimens of plant health deficiencies, allowing local specific analysis.

Moreira (2005) states that the main purpose of the indices is to highlight the spectral behavior of the vegetation in relation to the soil and to enhance the contrast, NDVI being one of the most commonly used because it is more sensitive to sparse vegetation.

NDVI consists of an equation whose variables are the red and near infrared bands (Moreira, 2005): NDVI: (IR-R) / (IR+R). Where, IR: Infrared (Near Infrared) and R: Red (Red).

LiDAR sensors perform laser scans that allow analysis of topography and forest cover analysis, and becoming an important tool for managers as they provide accurate information on tree height and biomass (Wagner & Ullrich, 2006). Another advantage of LiDAR sensors

on UAVs, especially compared to satellite imagery, is that they allow mapping the terrain under the trees and the estimated height of the plants simultaneously. This is possible because LiDAR sensors have their own energy source, the laser, which emits electromagnetic radiation in short waves to detect atmospheric changes (Andersen, 2006). Integrated data modeling makes it possible to analyze other urban forests variables in a short time that are important to managers in this environment, such as basal area, diameter, volume, biomass, carbon, and fuel.

Remote sensing and Geographic Information System (GIS) techniques are combined to map land use and land cover changes and measure the rate of urban expansion and vegetation loss (Ifatimehin & Ufuah, 2006). Pauleit and Duhme (2000) used a geographic information system to assess the spatial pattern and environmental functions of urban forest in the city of Munich, Germany. The spatial pattern of urban forest was closely related to the overall zoning of different land uses and building density. The relationship between cover, size and age of woody vegetation and the occurrence of forest indicator birds was used to assess the role of urban forest in urban conservation, and potential habitat linkages of nearby forests were identified using GIS. In addition, that urban forest was shown to be effective in reducing air temperature on hot summer days.

Narulita et al. (2016) used GIS to investigate the spatial distribution of urban forest in Bandung City, Indonesia, and developed a method to focus on the location for urban forest design. The method used considered several parameters: elevation, slope, land cover, climate, population density, and distance to the road. Priorities for urban forest development included three factors: biophysical, economic and social. The biophysical factors were land price index and the social factors were population density. Zheng et al. (2019) considered similar parameters for to compare the visual and ecological sensitivities of Tianzhu Mountain Forest Park, located in Fujian, South China, using the Analytical Hierarchical Process (AHP) in a GIS.

Other promising computational tools include Artificial Intelligence (AI) and the consequent Machine Learning. AI is a branch of computer science that proposes to develop devices that simulate the human capacity to think, perceive, make decisions and solve problems. Based on recent advances in computer vision and machine learning applied to convolutional neural networks (CNN), Branson et al. (2018) conducted experiments on street trees in the city of Pasadena, California, USA, and showed that it is possible to recognize more than 70 % of street trees, assign the correct species to more than 80 % of the 40 most common tree species, and correctly detect and classify changes in more than 90 % of cases.

In the inventories of Urban Forest, the individual recording of tree diagnosis or maintenance is generally not systematized, and when it is done it is still generally done on sheets of papers. The lack of appropriate tools for management can have a negative impact and lead to problems ranging from incompatibility with urban infrastructure to fallen trees,

therefore, an Urban Forest Management System, based on the application of computers and using technologies for mobility, management, storage and data integration, contributes to the management of the environment. These systems must enable the inventory, planning and planting of trees reliably and with minimal effort. A database gains more importance when it involves others who operate directly or indirectly in the urban forest, such as electricity companies that carry out tree pruning to avoid power interruptions caused by falling branches or trees, the water, sewage and telephone companies that interact with the tree in the distribution of theirs services (galleries or underground installations), or the Public Ministry, in terms of defining responsibilities for inadequate management (pruning or removal), casualty accidents or loss and material goods caused by a fallen tree in the city (Viríssimo et al., 2013).

Regarding the management of urban forests, it is observed that municipal public policies have an emergency character and act only in case of accidents involving human lives and material goods, imminent danger from falling trees and degradation of forest fragments. Moreover, there is still a great distance between the data generated by universities and research institutes and their application in the public administration of cities, probably due to the complexity of the data or its dispersion in several banks. In a smart and sustainable city, this management must have a preventive character, enabled by the availability of a large amount of data obtained in real time (Instituto de Pesquisas Tecnológicas do Estado de São Paulo, 2020). According to Lemos (2013), Smart City is synonymous with a metropolis where everything is tuned to the environment and produces, consumes and distributes a large amount of information in real time. It refers to computerized processes that are important to the context and use a huge amount of data (big Data), cloud networks and autonomous communication between various objects (Internet of Things). This intelligent processing will support and guide decision-making of businesses governments and citizens, with the aim of making urban economic, social, environmental and political activities more efficient and sustainable. Building a smart city requires an integrated and interdisciplinary action between specialists, scientists and city governments to understand the needs of the population.

Many studies about people participation in issues related to Urban Forest have been made and researchers have used the resource of questionnaires to collect data for the research (Bêrni, 2002). This type of questionnaire was planned for the construction of the Municipal Plan for Urban Afforestation of the City of São Paulo (PMAU), provided for in Law nº 16.050 of the Strategic Master Plan, as an important part of the information collection. Before creating the questionnaire, a survey is usually conducted on the questions to be created in order to achieve the objectives of the paper. The use of simple and understandable language that can be understood by different profiles of respondents and the ideal number of questions that do not take much time for the respondents are some of the strategies that should be used in the application of questionnaires.

Conclusion

The urban forest provides well-being and offers countless benefits to urban living, but cutting trees scheduling them below needs makes it impossible to maintain all the environmental services they provide. The use of management tools for the urban forest are necessary and more agile resources that can help managers in decision making for building a more sustainable and inclusive city.

References

Amato-Lourenço, L., Moreira, T., Arantes, B., Silva Filho, D., & Mauad, T. (2016). Metrópoles, cobertura vegetal, áreas verdes e saúde. *Estudos Avançados*, *30*(86), 113-130. Retrieved on May 3, 2021, from http://www.revistas.usp.br/eav/article/view/115084

Andersen, H.-E., Reutebuch, S. E., & McGaughey, R. J. (2006). A rigorous assessment of tree height measurements obtained using airborne LiDAR and conventional field methods. *Canadian Journal of Remote Sensing*, *32*(5), 355–366. https://doi.org/10.5589/m06-030

Bêrni, D. A. (2002). *Técnicas de pesquisa em economia: transformando curiosidade em conhecimento.* São Paulo.

Biondi, D. (2015). Floresta urbana: conceitos e terminologias. *In* D. Biondi (org.), *Floresta urbana.* Curitiba: O Autor.

Borges, M. G., Rodrigues, H. L. A., & Leite, M. E. (2019). Sensoriamento remoto aplicado ao mapeamento do Cerrado no Norte de Minas Gerais e suas fitofisionomias. *Caderno de Geografia*, *29*(58). ISSN 2318-2962.

Branson, S., Wegner, J. D., Hall, D., Lang, N., Schindler, K., & Perona, P. (2018). From Google Maps to a fine-grained catalog of street trees. *ISPRS Journal of Photogrammetry and Remote Sensing,135*,13-30.

Buckeridge, M. (2015). Árvores urbanas em São Paulo: planejamento, economia e água. *Estudos Avançados, 29*(84), 85-101. https://dx.doi.org/10.1590/S0103-40142015000200006

Carbone, A. S. (2014). *Gestão de áreas verdes no Município de São Paulo, SP - Brasil: ganhos e limites,* (Dissertação de mestrado). Faculdade de Saúde Pública, Universidade de São Paulo, São Paulo. doi: 10.11606/D.6.2014.tde-09042014-103047. Retrieved on March 19, 2021, from http://www.teses.usp.br

Cavalheiro, F., & Del Picchia, P. C. D. (1992). Áreas Verdes: conceitos, objetivos e diretrizes para o planejamento. *1 Congresso Brasileiro Sobre Arborização Urbana* (pp. 29-35). Vitória - ES. v. I e II.

Crósta, A. P. (1992). *Processamento digital de imagens de sensoriamento remoto* (ed. rev.). Campinas: IG/UNICAMP.

Hamamura, C. (2020). *Sensoriamento remoto para identificação taxonômica e mapeamento de espécies arbóreas em ambiente urbano,* (Tese de doutorado). Escola Superior de

Agricultura Luiz de Queiroz, Universidade de São Paulo, Piracicaba. doi:10.11606/T.11.2020.tde-12082020-165438. Retrieved on August 28, 2020, from http://www.teses.usp.br

Harder, I. C. F., Ribeiro, R. C. S., & Tavares, A. R. (2006). Índices de área verde e cobertura vegetal para as praças do município de Vinhedo, SP. *Revista Árvore, 30*(2), 277-282.

Hassaan, O., Nasir, A. K., Roth, H., & Khan, M. F. (2016). Precision Forestry: Trees Counting in Urban Areas Using Visible Imagery Based on an Unmanned Aerial Vehicle. *IFAC-Papers On Line, 49*(16), 16-21.

Ifatimehin, O. O., & Ufuah, M. (2006). An Analysis of Urban Expansion and Loss of Vegetation Cover in Lokoja, Using GIS Techniques an Analysis of Urban Expansion and Loss of Vegetation. *The Zaria Geographer, 17*(1), 28–36.

Instituto de Pesquisas Tecnológicas do Estado de São Paulo. (2020). *Plano de Desenvolvimento Institucional na Área de Transformação Digital: Manufatura Avançada e Cidades Inteligentes e Sustentáveis*. São Paulo: IPT. 24 p. (2º relatório científico, Processo FAPESP: 2017/50343-2; Programa de Modernização dos Institutos Estaduais de Pesquisa).

Lemos, A. (2013). Cidades inteligentes. *GV-executivo*, *12*(2).

Morato, R. G., & Machado, R. P. P. (2015). Análise espacial da justiça ambiental no Distrito da Vila Andrade – São Paulo/SP. *Seminário Internacional Justiça Espacial e Direito à Cidade* (p. 21). São Paulo, SP: https://doi.org/10.13140/RG.2.1.3461.8645

Moreira, M. A. (2005). *Fundamentos do sensoriamento remoto e metodologias de aplicação*. Viçosa, MG: Editora UFV.

Narulita, S., Zain, A. F. M., & Prasetyo, L. B. (2016). Geographic Information System (GIS) Application on Urban Forest Development in Bandung City. *Procedia Environmental Sciences, 33,* 279–289. https://doi.org/https://doi.org/10.1016/j.proenv.2016.03.079

Nucci, J. C. (2001). *Qualidade ambiental e adensamento urbano*. São Paulo, SP: Humanitas.

Pauleit, S., & Duhme, F. (2000). GIS assessment of Munich's urban forest structure for urban planning. *Journal of Arboriculture,* 26(3), 133-141.

Prefeitura da Cidade de São Paulo. (2017). *Plano Municipal de Conservação e Recuperação da Mata Atlântica do Município de São Paulo - PMMA.* Retrieved on June 06, 2021, from https://www.prefeitura.sp.gov.br/cidade/secretarias/upload/PMMA_final_8_jan%20ok.pdf

Randrup, T. B., Dobbertin M. K., Bosch C. K., & Pruller, R. (2005). *The Concept of Urban Forestry in Europe*, (p.13). Europe.

Rezende, J. H., Aroni, L. R., & Rodrigues, V. L. (2020). Avaliação e classificação de praças com o uso de Veículos Aéreos Não Tripulados (VANT). *REVSBAU*, *15*(2), 75-89.

Ribeiro, T. G., Boaventura, G. R., Cunha, L. S., & Pimenta, S. M. (2017). Qualidade Ambiental: Reflexões Teóricas. *Revista Processos Químicos*, *11*(21), 37-45. https://doi.org/10.19142/rpq.v11i21.390

Rouse, J. W., Haas, R. H., Schell, J. A., Deering, D. W., & Harlan, J. C. (1973). *Monitoring the vernal advancement of retrogradation of natural vegetation*. Greenbelt: National Aerospace Spatial Administration, (371 p). MD: NASA/GSFC Type III, Final Report. Retrieved on June 06, 2012, from http://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/19730017588.pdf

Salbitano, F. (2019, May 08-11). Urban forest-based solutions for health: opportunities and threats of doctor green in our future cities. Paper presented at the *World Conference on Forests for Public Health*, Greece. (Abstract Book).

Silva, R., Lima, C., & Saito, C. (2019). Análise Per Capita dos Espaços Verdes Urbanos na Região Metropolitana de São Paulo - Brasil. *Revista do Departamento de Geografia*, *38*, 31-41. https://doi.org/10.11606/rdg.v38i1.156105

Sociedade Brasileira de Arborização Urbana – SBAU. (1996). Carta a Londrina e Ibiporã. *Boletim Informativo, 3*(5), 3.

Tyrväinen, L. (2019, May 08-11). Outdoor recreation and nature-based tourism for public health. Paper presented at the *World Conference on Forests for Public Health*, Greece. (Abstract Book).

United Nations – UN. (2012). *World urbanization prospects: the 2011 revision*. New York: ONU. Retrieved on June 06, 2012, from http://esa.un.org/unpd/wup/index.htm

Viríssimo, D. B., Russo, M. C., Brazolin, S., Amaral, R. D. A. M. (2013). Arbio: Sistema de Gestão da Arborização. *Conferência IADIS Ibero-Americana Computação Aplicada*, São Leopoldo, RS.

Wagner, W., & Ullrich, A. (2006). Gaussian decomposition and calibration of a novel small-footprint full-waveform digitising airbone laser scanner. *ISPRS Journal of photogrammetry and Remote Sensing*, *60*(2), 100-112.

Zheng, Y., Lan, S., Chen, W. Y., Chen, X., Xu, X., Chen, Y., & Dong, J. (2019). Visual sensitivity versus ecological sensitivity: An application of GIS in urban forest park planning. *Urban Forestry & Urban Greening, 41*, 139–149. https://doi.org/https://doi.org/10.1016/j.ufug.2019.03.010