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Prediction models for estimating pruned biomass obtained from *Platanus hispanica* Münchh. used for material surveys in urban forests

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ABSTRACT

The amount of urban biomass waste derived from pruning operations represents a potential source of bioenergy little studied or considered in local bio-economies. This research focused on direct quantification of lignocellulosic residual biomass yielded during tree pruning, characterization of basic tree parameters and development of indirect biomass prediction models. Sample individuals of 30 *Platanus hispanica* Münchh. with mean diameter at breast height 23.56 cm, crown diameter 8.44 m, crown base height 3.76 m, and total height 11.57 m were examined. Wood formed 43.34% of pruned biomass before the drying process and wood moisture content in wet basis reached 40.16%. Mean quantity of dry biomass obtained per tree was 23.98 kg and standard deviation was 15.16 kg. Allometric relationships were analyzed. Significant coefficients of determination were observed for dry biomass and diameter at breast height ($R^2 = 0.87$), as well as for dry biomass and conical and parabolic crown volume ($R^2 = 0.78$). The best result ($R^2 = 0.93$) was obtained from a multiple regression model with several explicative variables. Indirect biomass prediction equations and characteristics of yielded residuals derived from this research can be useful for biomass planning and management purposes. These equations can be implemented for urban inventories, and the application of logistic models. The significance of this topic is beyond doubt for urban environment, especially for the possibilities of reducing carbon dioxide emissions and perspectives of biomass utilization as a biofuel.

1. Introduction

The urbanization process of land has been increasing sharply in great scale throughout the last years. Urban areas transform and displace forests, agricultural areas and other value open spaces. As this process continues to expand, the importance of presence of urban forests, their impact on local, regional and global environments and influence on great majority of population becomes stronger [1]. The European Environment Agency (EEA) [2] estimates the urban forest surface within municipal boundaries between 5% (Madrid) and 60% (Bratislava), while Pauleit et al. [3] at the level from 1.5% (Thessaloniki) up to 62% (Ljubljana). Ottitsch [4] points out an average of approximately 30% (5%–56%) or 6–7000 m^2/inhabitant of green space for 14 surveyed European cities. In a research by Konijnendijk [5], average woodland cover within municipal boundaries of 26 larger European cities is estimated at 18.5% (104 m^2/inhabitant). Urban biomass research commonly includes entire cities and regions. Nevertheless, there is lack of focus on individual tree biomass [6]. Pillsbury et al., [7] note, that the urban forest inventories should include composition, structure and volume of urban trees. Apart from species location, health or damage rating, dimensional tree parameters such as diameter at breast height and total tree height should be collected.

Maintenance and renovation of green zones within municipal boundaries requires removing grass, foliage of trees and shrubs, branches, entire trees and shrubs, harvest from vines and hedges, herbaceous and waterside vegetation, all at different stages of vegetation, various moisture content and stage of decomposing. The quantity of removed residuals is proportional to the health and growth intensity of vegetation and varies depending on soil fertility, irrigation, climatic conditions as well as frequency and type of maintenance operations [8]. Urban tree and woody yard residuals form an important component of the municipal solid waste stream. In most cases, plant mass is treated as one stream, loaded into containers and transported to landfills [9]. Only a part of these residuals are recovered for composting, recycling, biogas production, fertilization or solid biofuel production such as pellets and briquettes. Systematic removal of organic material from urban

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green areas decreases soil fertility and eventually its productivity [10,11]. Depending on country, these loses are compensated by use of external origin compost and mineral fertilization [10] or by mulching extracted biomass and leaving it *in situ* [11]. McFarlane [12] notes, that urban wood biomass is rather an extensive than intensive resource, although land clearing and destructive weather events can lead to an increased amount of lignocellulosic residuals in short periods of time. Moreover, the logistics of collecting and utilizing urban residual biomass is incomparable with harvesting from point sources such as plantations [13].

Pruning is held to maintain the highest standing biomass and only to remove dangerous or damaged parts, what makes it impossible to estimate mean weight of woody residuals per species. Due to differences in biomass treatment, management policies, environmental awareness, accessible technology and economical background, the quantity of plant mass removed under pruning will significantly vary on local, national and international level. Generally, research on urban tree wood biomass estimates was done for whole aboveground biomass, using models for forest-grown softwoods and hardwoods. Forest-derived biomass equations are believed to overestimate biomass from urban species [14]. Equations used for biomass prediction normally apply parameters such as diameter at breast height, tree height and crown dimensions to yield all aboveground biomass estimates. In general, research conducted on urban settings has been limited [15] (Peper et al., 1998) and there is lack of homogenous results. Variables that affect tree growth, such as site characteristics (soil, water irrigation, density of buildings, etc.) and climatic conditions are different among cities, what causes that allometric relationships will vary [6,16,17]. Management practices also influence biomass production and allocation within trees in landscape [18,19]. Droppelman and Berlier [20] argue that pruning may affect the rate of biomass accumulation as cutting and pruning can affect the quantity of biomass without changing the diameter at breast height (dbh). For that, allometric equations based on dbh should include other parameters such as height, wood density, or crown area to improve accuracy [21,22]. At the moment, studies concentrated on developing methods for predicting and quantifying residual biomass originating particularly from pruning operation of urban trees, to our knowledge, seem unavailable or unpublished.

This research continues the evaluation of predicting and using lignocellulosic biomass from urban boundaries, particularly as a renewable energy source or raw material for industry, which has been started by Sajdak and Velázquez-Martí [23–25] and expanded to the use of LIDAR systems [26,27]. The presented paper focuses on *Platanus hispanica* Münchh., which is extensively cultivated as an ornamental tree in parkland and roadside areas in the temperate regions. Due to its high resistance to insect attacks, atmospheric pollution of large cities and root compaction as well as rapid growth and great ease for transplantation it became popular in urban zones [28,29]. Because of large areas of cultivation of this species in Mediterranean urban forests, the quantification and assessment of its residual becomes important. This research concentrated on direct quantification of biomass yielded in crown raising type of pruning, development of indirect biomass prediction models based on basic tree dimensional parameters and dendrometric characterization of woody residuals which can be used for urban forest management and inventory needs.

2. Materials and methods

2.1. Field study

The research area was located in Alcudia, city in the province of Valencia (39°28′50″N, 0°21′59″W). The area is defined with average annual temperature, rainfall and humidity of 17.8 °C, 454 mm and 65%, respectively [30]. For study purposes a total of 30 individuals of *Platanus hispanica* Münchh. were randomly selected from a municipal street with dense car and pedestrian traffic. Field studies were confined due to limits related to coordination of maintenance practices of the pruning company and field data collection. Nevertheless, the tree sample is considered to represent a sufficient size distribution of the *Platanus hispanica* Münchh. population. During field trials, sample trees were numbered sequentially, following the direction of traffic. Next, basic tree parameters were measured manually before the pruning process started:

- Tree data: diameter at breast height (cm), crown diameter (m), crown base height (m), total tree height (m),
- Tree management information: date and type of last pruning operations.

The examined *Platanus hispanica* Münchh. sample is characterized by the following dimensions: diameter at breast height 11.2–45.5 cm, crown diameter 4.1–13.3 m, crown base height 2.2–5.6 m and total tree height 6.4–17 m, respectively. All sample trees were pruned each three years under uniform crown raising type of pruning practice (Figs. 1 and 2). This type of pruning consists of removal of lower branches in order to provide crown elevation clearance for pedestrian and vehicle traffic and to ensure open views, visibility of traffic lights and signs [31]. For that, lower lateral branches are cut down systematically, but without eliminating more than those that are clearly in excess until the trunk reaches 1.5–2 m in height [32]. This prevents the low branches from growing to a large diameter and allows the wounds to heal better than in old trees. The regulation of the crown elevation is designed to adapt the tree to different situations where it is situated as well as to respond to aesthetic needs [31]. In this study crown raising was performed on young and medium-aged trees.

2.2. Field and laboratory measurements

Trunk diameters (dbh) in small trees were measured with a traditional aluminium calliper and in case of big trees with a diameter tape, at a point 1.3 m aboveground level on the uphill side, both with precision 0.001 m. Crown diameter (dc) was measured with a diameter tape with precision 0.001 m. Due to irregularities in the crowns' outline, the diameter was determined by averaging measurements of the long axis diameter with a diameter taken at right angle. The total tree height (h) and the crown base height (hc) were measured with a Vertex IV hypsometer with precision 0.01 m [34–36]. Once pruning operations have finished, the residual biomass was formed in bundles and weighted by means of a dynamometer with precision 0.01 kg. Weight measurements were carried out in field conditions. 17 branches of each sample tree were defoliated to determine the percentage of foliage and wood mass. Sample branches were collected for further dendrometric calculations.

For the purpose of laboratory analysis, wood samples were collected in plastic containers for moisture content determination. The evaluation of the drying process was done according to the UNE-EN 14774-2 standard [37] and took place in two types of conditions. Open-air drying was carried out in laboratory environment with average temperature 21.32 °C and relative humidity 42.41%. A daily record of results took place until the stabilization of weight was obtained. When oven drying, samples were placed on metal trays and located in a stove with controlled temperature (105 ± 2) C. The drying time didn't exceed 24 h in order to avoid possible unnecessary loss of volatile substances.