PREDICTION MODELS TO ESTIMATE PRUNNED BIOMASS OF *PLATANUS HISPANICA* TO DO RAW MATERIAL SURVEYS FROM URBAN SYSTEMS

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Abstract

The amount of biomass waste originated from pruning operations represents a potential source of renewable energy little studied or considered in a local system. The necessity of quantifying urban wood biomass, creating a comprehensive database on its dendrometric characteristics and forming a dependence diagnosis between basic tree parameters and the quantity of biomass obtained from pruning operations was considered the case of this study. Sample individuals of 30 Platanus hispanica with mean diameter at breast height 23.56cm, mean crown diameter 8.44m, mean distance from soil to the crown 3.76m, and mean total height 11.57m were examined. Wood formed 43.34% of total weight of all pruned material before a drying process, wood moisture content in wet basis was 40.164% and mean quantity of dry biomass obtained per tree was 23.98kg. Classical dendrometry measurement methods were adapted and relationships between dendrometric tree parameters and weight of dried pruned biomass were developed, by means of regression models. Significant relationships were observed between quantity of dry biomass and diameter at breast height (R^2=0.87), as well as between dry biomass and conical and parabolic crown volume model (R^2=0.76). Methods for estimating the *amount of residual biomass generated in each tree and their characteristics can be useful for planning. Therefore, technical application can be quickly taken by the managers in urban areas. They can be used for urban inventories, and the application of logistic models. The significance of this topic is no doubt for urban environment, especially for reduction of carbon dioxide emission possibilities and perspectives for biomass utilization as a biofuel.*

Keywords: Urban forest, urban biomass waste, allometric relationships, volume equations

INTRODUCTION

It is estimated that woody waste originated from pruning operations of urban forests is a potentially abundant and underutilised resource of biomass that could contribute significantly as an income in the regional and national bioeconomies. Moreover, the utilization of urban wood residual biomass could offer bio-based fuels for heat and power generation and decrease waste disposal costs (MacFarlane, 2009). Numerous studies have analysed the costs, benefits and carbon storage capacity of urban forests. Nevertheless, these studies are limited by the lack of research on urban tree biomass. Moreover, the estimates of carbon storage in urban environments mainly rely upon allometric relationships developed for trees in traditional forests (McPherson et al., 2005, Pataki et al., 2006). More exact quantification of urban wood biomass may depend on development of allometric relationships especially for urban trees. Reasons exist to believe that allometry associated with traditional forests does not accurately represent urban systems. Characteristics such as low tree density in urban environments connected with the potential competition for resources are one important point (McHale et al., 2009). Growing in an open environment, urban forests frequently receive additional water and nutrient supply. In North America studies have shown that urban trees, including those located in areas considered as stressful, noted higher rates of trunk growth comparing to published rates for the same species in traditional forests. It is concluded to be a possible result of release from competition and above average precipitation (Rhoades et al., 1999). Trees in urban settings have different challenges comparing to trees locates in traditional forests such as damage, disease and pruning. The results indicated that soil moisture, air temperature, relative humidity, leaf temperature and vapour pressure deficit were less favourable for urban trees. This results mainly in slower growth, lower root density and earlier leaf drop. Study published by Pillsbury et al. (1998) developed equations for urban trees in the United States of America. A research by McHale et al. (2009) measured standing tree volume using an optical dendrometer and converted volume to biomass with the use of gravity values for individual tree species. For each species, estimates of total tree volume and diameter at breast height (DBH) were evaluated. Studies on urban based specific gravity are not found in literature, nevertheless specific gravity is known to change with water and nutrient inputs (Nyakuengama et al., 2002).

It is known that vegetation of urban, leisure, industrial and communication areas plays significant ecological, scenic and aesthetic functions, contributing to improving the quality of life in the urban surrounding. While urban vegetation was used primarily as a tool for ornamental purposes, it is important nowadays to focus on its role in environmental improvement. Few studies have estimated the impact of the urban forest wood on environmental quality, such as residual biomass, which can be used to achieve ecological and energy targets. Currently, municipalities are forced to destiny a relevant percentage of their budgets for the maintenance of urban green space. Nevertheless, only a minor share of woody residuals is being recovered and few processes are applied to generate income that can offset the expenses of this operation (McKeever et al., 2003, USDA, 2002). A great share of urban wood ends up in landfills (MacFarlane, 2007). Moreover, the lack of precise information on the basic characteristics of species in relation with potential biomass is a barrier to the rational use of this material and the achievement of social benefits. The frequency and type of pruning operations have a key influence on the quantity of the material produced (Drénou, 2006).

This work continues the study carried out to evaluate the possibility of using wood biomass from urban areas, particularly as a renewable energy source, which was started by Sajdak and Velázquez (2012). Now, the presented paper is focused on *Platanus hispanica,* which is extensively cultivated as ornamental tree in parkland and roadside in the temperate regions. Due to its high resistance to insect attacks, atmospheric pollution of large cities and root compaction, it became popular in urban zones (De La Torre, 2001). It is characterized by a rapid growth, great ease for transplantation and supports pruning operations well (López González, 2010). Because of large areas where this species is cultivated in Mediterranean urban forests, the quantification and assessment of its residual becomes important. For this, it is key to establish the quantification of biomass received under particular pruning operations, develop relationship between basic parameters as tree height, diameter at breast height, crown diameter, crown volume and quantity of biomass obtained as well as adapt dendrometric methods for urban forest measurement needs.

MATERIALS AND METHODS

Field study

The study area was located in Alcudia, a city in the east of Spain in the province of Valencia. The procedure of trial consisted on a random selection of a municipal street of dense car and pedestrian traffic and 30 individuals of *Platanus hispanica* pruned under uniform crown raising type of pruning practice. Previously to carry out pruning operations, the identification of the selected individuals was performed. Following data were measured:

-Tree data: diameter at breast height (cm), crown diameter (m), distance from soil to the crown (m), total tree height (m)

-Tree management information: date and type of last pruning operations

A total of 30 individuals of *Platanus hispanica* with diameter at breast height between 11.2cm and 45.5 cm, crown diameter between 4.1 m and 13.3 m, distance from soil to the crown between 2.2 m and5.6 m and total tree height between 6.4 m and 17 m were examined. All sampled trees were pruned each three years under uniform crown raising type of pruning practice (Figures 1 and 2). This type of pruning consisted of removal of lower branches in order to provide crown elevation clearance for pedestrian and vehicle traffic as well as open views, visibility of lights and signs (Michau, 1987). The lower lateral branches were cut down systematically, but without eliminating more than those that are clearly in excess until the trunk reaches 1.5-2 m in height (Gil-Albert, 2001). Crown lifting was performed on young and medium-aged trees. 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 was designed to adapt the tree to the different situations where it is situated as well as respond to the aesthetic requirements (Michau, 1987).

Figure 1. Crown raising applied to *Platanus hispanica* trees (adapted sheme of Bedker et al., 1995)

Figure 2. From left to right: Crown raising of *Platanus hispanica*; residual transport

To measure trunk diameters a traditional aluminium calliper was used, for crown diameter a tape measure, and for the height a Vertex IV hypsometer. Once pruning operations ended, the residual biomass was formed in bundles and weighted by means of a dynamometer. Weight measurements were carried out in field conditions. Samples of wood were put into small plastic containers in order to determine moisture content in laboratory conditions and obtain dry matter results. Evolution of the drying process was carried out in two types of conditions: open-air drying with average temperature 21.32ºC and relative humidity 42.41%, stove drying with temperature 105°C. In both cases, a daily record of results was made until the stabilization of weight. Several branches of each sample-tree were defoliated to determine the percentage of foliage and wood mass. Sampled branches were collected for further dendrometric calculations.

Dendrometric analysis of the branches

The dendrometric analysis has been focused on developing methods to calculate easily the actual volume of particular tree structures. For this, two approaches were carried out: morphic coefficient *f* (also called form factor) and volume functions were studied. Morphic coefficient *f* is defined as the ratio between the actual volume and a geometric model volume taken as reference (Eq. 1) (Velázquez et al, 2010). The models that provide the form factor most approximate to 1, define best the shape of the branch. Volume functions are equations that give the actual volume of a branch from indirect measurements. The form factor and volume functions allow determining the volume of any structure by measuring the basal diameter and length.

$$f = \frac{V}{Vgs} \qquad (1)$$

Where V is volume of branch (m3), Vgs is volume of a geometrical solid of same diameter and height (m^3)

Actual volume determination was carried out on sample branches collected after pruning operations. To perform this study several sample branches of each species were selected. To calculate the actual volume of a branch, it was divided into equal sections with the length of

20 cm (Figure 3). The volume was calculated by the following equations (Table 1) (Lopez Serrano et al., 2003; Velazquez et al., 2009; West, 2009). This method measures a branch in short sections, determines the volume of each section and sums them up to obtain the total volume.

Table 1. Equations for volume of each branch section

Sectional Volume Formulae	Equation for Volume
Huber`s formula	$v_r = \frac{\pi}{4} \cdot dm \cdot l$
Smalian`s formula	$v_r = \frac{\pi}{8} \cdot (dl^2 + du^2) \cdot l$
Newton`s formula	$v_r = \frac{\pi}{24} \cdot (dl^2 + du^2 + 4dm^2) \cdot l$

v_r: real volume of a section (cm^3); dl: large end diameter at the lower end of a section (cm); du: small end diameter at the upper end of a section (cm); dm: diameter midway along a section (cm); l: length of a section (cm)

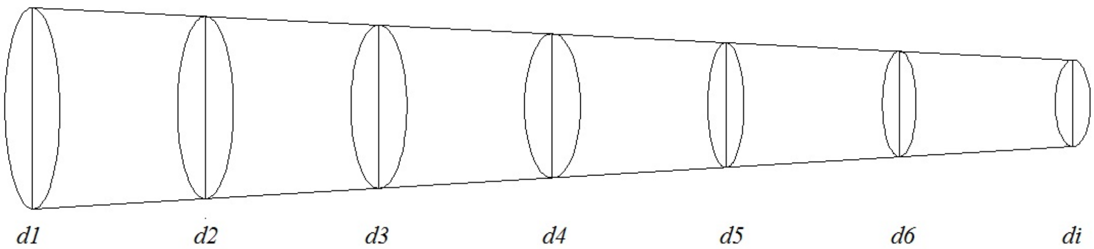

Figure 3. Measurements of diameters in each interval

When assuming the shape of a branch to resemble the form of solids of revolution, equations used to compute the volume of cones, cylinders, paraboloids and neiloids were used to calculate the model volume of a branch (Table 2) (Husch et al., 2003).

Table 2. Equations to compute volume of solids of revolution

Geometric solid	Equation for volume
Cylinder	$v_m = \frac{\pi \cdot d_o^2}{4} \cdot h$
Paraboloid	$v_m = \frac{1}{2} \frac{\pi \cdot d_o^2}{4} \cdot h$
Cone	$v_m = \frac{1}{3} \frac{\pi \cdot d_o^2}{4} \cdot h$
Neiloid	$v_m = \frac{1}{4} \frac{\pi \cdot d_o^2}{4} \cdot h$

v_m: model volume (cm^3); d_o: base diameter of a branch (cm); h: length of a branch (cm)

The form factor could be influenced by the base diameter and length of the branch. This influence was analyzed.

In principle, the form factor should be a parameter characteristic of the species and diameter class. However, for each of the tests performed there is a statistical variability. For this the mean and standard deviation for each of the cases have been determined.

In order to define volume functions regression models of Table 3 were analyzed, considering as dependent variable the total volume of the structure (V) in cm^3, and as independent variables the base diameter (d_0) in cm and total height of the structure (h) in cm. To determine the volume function that provides the best fit, the coefficient of determination (R^2), standard deviation (sd) and mean absolute error (MAE) were calculated. The material used in this trial was a digital caliper and a tape measure with precision 0.01 mm and 0.001 m, respectively.

Table 3. Branch volume functions

Author	Equation
Naslund (modif), (Naslund, 1940)	$V= b_0 + b_1d_0^2 + b_2d_0^2l + b_3d_0l^2$
Spurr (Spurr, 1952)	$V= b_0 + b_1d_0^2l$
Ogaya (Dieguez Aranda et al., 2003)	$V= b_1d_0^2 + b_2d_0^2l$
Hoenald-Krenn (Hohenald, 1936)	$V= b_0 + b_1d_0 + b_1d_0^2$

V: volume of the branch (cm^3); d_o: base diameter of a branch (cm); l: length of a branch

Crown volume estimation, prediction models

Apparent volume of a tree crown was related with the quantity of biomass obtained under pruning operations. The apparent volume of a tree crown was determined using basic parameters: crown diameter, total tree height and distance from soil to the crown collected during field study. Next, equations for apparent volume calculation for particular solids of revolution were applied. It is assumed, that growth models of tree crowns resemble the form of hemispheric, parabolic and conical growth (Table 4) (Dieguez et al., 2003).

Table 4. Growth models

Geometric solid	Equation for Volume
Cone	$vc = \frac{\pi \cdot dc^2 \cdot hc}{12}$
Paraboloid	$vc = \frac{\pi \cdot dc^2 \cdot hc}{8}$
Hemisphere	$vc = \frac{\pi \cdot dc^3}{12}$

Where *vc* is crown volume (m^3);*dc* is crown diameter (m);*hc* is crown height (m)

Regression models for biomass prediction

The most common approach to biomass estimation is to develop non-destructive measurement. For this multiple linear regressions (allometric functions, biomass estimation functions) were studied by the Statgraphics 5.1 software. A variety of regression models have been developed in order to predict biomass from plant measurement. Regression equations used as explicative variables diameter at breast height, crown diameter, total height or a combination of these variables. To validate the equations, two independent data sets have been organized: one set (n=25) to generate the model and one set (n=5) for its validation. These models are marked with an * and some validation results are attached in the annexes. A t-test has been used to compare the mean of real values and values calculated by a regression model and an analysis of residual plots has been performed.

RESULTS AND DISCUSSION

Sample trees were characterised with mean diameter at breast height 23.56 cm, mean crown diameter 8.44 m, mean height from soil to the crown 3.76 m and mean total height 11.57 m. In this work could be noted that wood formed 43.34% of total weight of all pruned material before drying. The rest 56.66% of weight was formed by leaves and fruit. Wood moisture content was 40.164% in wet basis. The mean and dispersion obtained comparing all sample trees analyzed according to the quantity of residual biomass were 23.98 kg of dry wood biomass per tree and standard deviation 15.16 kg. A test was made to check if the dendrometric parameters follow a normal distribution. This was done by verifying, if the skewness and the kurtosis are between -2, +2, by the Statgraphics 5.1 software and P-values of the Shapiro Wilks test are higher than 0.05. The results are presented in Table 5. The variable analysis indicates that the standardized skewness and kurtosis values are within the range expected for data from a normal distribution. The tree-sample includes individuals with small to large canopies and heights.

Table 5. Variable analysis of *Platanus hispanica* trees

Variable	Average	Standard deviation	Standard skewness	Standard kurtosis	Shapiro Wilks test (P-value)	Maximum	Minimum
Diameter at breast height (cm)	23.56	7.92	1.12	0.56	0.303	45.50	11.20
Crown diameter (m)	8.44	2.41	0.37	-0.86	0.778	13.30	4.10
Total tree height (m)	11.57	2.38	0.55	0.26	0.795	17.00	6.40

Figure 4 shows the variation of moisture content during the evaluation of the drying process carried out in open-air drying conditions. It is observed that the minimum moisture content in open-air was obtained after 29 days and in stove drying conditions after 24 hours. Dry matter results allow calculating the amount of dry wood biomass obtained from pruning operations.

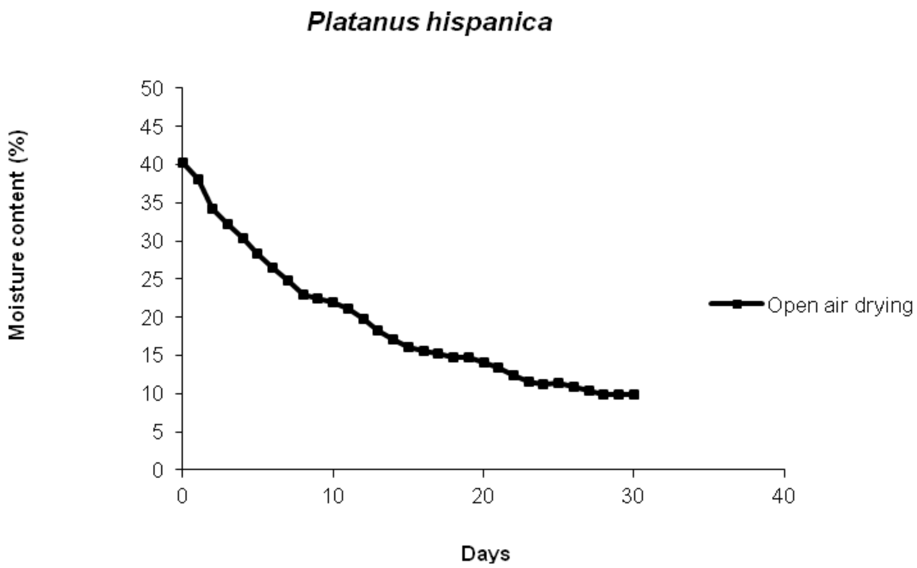

Figure 4. Drying curve for *Platanus hispanica in open air*

Branch form factor and volume functions

Table 6 shows the results of mean and standard deviation values of the branch form factors obtained from different models for Platanus hispanica. The model that produced a form factor closest to 1 was the cylinder. This model represented the best fit to characterize the actual volume.

Table 6. Mean and standard deviation of form factor of sample branches of *Platanus hispanica*

Model volume	Real volume					
	Huber		Newton		Smalian	
	f	sd *f*	*f*	sd *f*	*f*	sd *f*
Cylinder	0.72	0.11	0.72	0.11	0.71	0.11
Paraboloid	1.45	0.23	1.44	0.23	1.43	0.22
Cone	2.18	0.35	2.17	0.34	2.14	0.34
Neiloid	2.91	0.47	2.89	0.46	2.86	0.45

f : mean form factor; sd*f* : standard deviation of form factor

The variation of the form factor from the base diameter and length of the branches was studied by means of regression models. The coefficients of determination, standard deviation and mean absolute error are presented in Table 7. The low values of R^2 can indicate that the form factor is not dependent of these variables. Therefore, if this technique is used to calculate the volume, the mean must be used, although the P-values of all explicative variables was less than 0.05, which means a statistically significant relationship between the variables at the 95.0% confidence level.

Table 7. Regression model to describe the relationship between f and 2 independent variables do, h in branches of *Platanus hispanica*

Equation	R^2	Sd	MAE
f = 0.878299 + 0.0996161*do – 0.00478805*h	0.50	0.08	0.07

f: form factor; R^2: coefficient of determination; sd: standard deviation; MAE: mean absolute error; do: base diameter of a branch (cm); h: length of a branch (cm)

On the other hand, Table 8 shows the results of adjusting the volume functions for *Platanus hispanica* branches. For each model, were obtained the coefficient of determination, standard deviation and mean absolute error.

Table 8. Branch volume functions for *Platanus hispanica*

Author	Volume function	R^2	sd	MAE
Naslund (modif)	$V = -0.96235 + 3.02575 \cdot do^2 + 0.681096 \cdot do^2 \cdot l - 0.00375207 \cdot do \cdot l^2$	0.99	21.63	13.50
Spurr *	$V = -11.2731 + 0.620237 \cdot do^2 \cdot l$	0.99	27.14	19.13
Ogaya	$V = -21.0495 + 15.4334 \cdot do^2 + 0.457927 \cdot do^2 \cdot l$	0.99	22.39	15.74
Hoenald-Krenn	$V = 56.5386 - 106.076 \cdot do + 80.7595 \cdot do^2$	0.97	36.95	25.20

R^2: coefficient of determination; sd: standard deviation; MAE: mean absolute error; V: volume of a branch (cm^3); do: base diameter of a branch (cm); l: length of a branch (cm); * best equation validated with independent data

The coefficients of determination (R^2) for all the analyzed models were high. Although Naslund equation had the highest R^2 value, all its explicative variables were not significant. The volume function that presented the lowest P-values in its variables was Spurr. Table 9 presents a detailed statistical analysis of the selected volume functions. The P-value is less than 0.05. There is a statistically significant relationship between the variables at the 95.0% confidence level.

Table 1. Significance of explicative variables for Spurr volume function for *Platanus hispanica* branches

Dependent variable: V
Independent variables: $do^2 \cdot l$

Parameter	Estimate	Standard error	T statistic	P-Value
Constant	-11.2731	11.6888	-0.964431	0.3576
$do^2 \cdot l$	0.620237	0.0201921	30.7167	0.0000

V: volume of a branch (cm^3); do: base diameter of a branch (cm); l: length of a branch (cm)

Regression models for biomass prediction

Following regression models were calculated to predict the amount of residual biomass from crown raising pruning operations of *Platanus hispanica* from simple measures such as diameter at breast height, crown diameter and total tree height (Tables 10 and 11). The statistic variables in Table 11 indicate, that there is a high interdependence between residual biomass and diameter at breast height with a coefficient of determination at the level R^2 =0.87 in the quadratic model. This indicates a good explanatory power for predicting biomass. There is also an interdependence between the residual biomass and crown diameter at the level R^2 =0.68 in the quadratic model. The P-values of all explicative variables were less than 0.05. This indicates that there is a statistically significant relationship between the variables at the 95.0% confidence level.

Table 10. Regression models to describe the relationship between the pruned biomass (B) and only one independent variable for *Platanus hispanica*

Residual biomass versus diameter at breast height (dbh)	
Type of equation	Equation
Linear	B = -16,4074 + 1,71395*dbh
Quadratic	B = 2,83173 + 0,0343369*dbh^2
Residual biomass versus crown diameter (dc)	
Type of equation	Equation
Linear	B = -18,6037 + 5,04282*dc
Quadratic	B = 1,03702 + 0,298084*dc^2
Residual biomass versus total tree height (h)	
Type of equation	Equation
Linear	B = -31,7936 + 4,81816*h
Quadratic	B = -5,1046 + 0,208479*h^2

B: dry biomass (kg)

Table 11. Multiple regression analysis for *Platanus hispanica*

Residual biomass versus diameter at breast height (dbh)			
Type of equation	R^2	sd	MAE
Linear	0.80	6.88	5.11
Quadratic	0.87	5.55	4.30
Residual biomass versus crown diameter (dc)			
Type of equation	R^2	sd	MAE
Linear	0.64	9.17	6.43
Quadratic	0.68	8.60	6.02
Residual biomass versus total tree height (h)			
Type of equation	R^2	sd	MAE
Linear	0.57	10.06	7.20
Quadratic	0.61	9.55	7.18

R^2: coefficient of determination; sd: standard deviation; MAE: mean absolute error

In addition, regression models for predicting residual biomass were tested from combinations of variables such us diameter at breast height, crown diameter and total tree height, but the this not improve the R^2 value (R^2= 0.93) (Table 12). The P-values are less than 0.05, for that there is a statistically significant relationship between the variables at the 95.0% confidence level.

Table 12. Regression model to describe the relationship between biomass and dendrometric variables for *Platanus hispanica*

Equation*	R^2	sd	MAE
$B = 3.3003+ 0.270102 \cdot dc \cdot dbh - 0.500268 \cdot dc^2$	0.93	4.52	3.32

R^2: coefficient of determination; sd: standard deviation; MAE: mean absolute error; dbh: diameter at breast height (cm); dc: crown diameter (m); * best equation validated with independent data

Prediction models also calculated from the apparent volume of the crown were also analyzed. As observed in Table 13 there is a good linear relationship between the conical and parabolic volume model and the amount of dry biomass yielded from pruning (R^2=0.76). A minor difference is observed in the hemispheric volume model (R^2=0.71).

Table 13. Regression model to describe the relationship between biomass and independent variable crown volume for *Platanus hispanica*

Type of model	Equation	R^2	sd	MAE
Conical volume model *	$B = 6.10934 + 0.0992547 \cdot Vcone$	0.78	7.62	5.30
Parabolic volume model	$B = 6.10934 + 0.0661698 \cdot Vparaboloid$	0.78	7.62	5.30
Hemispheric volume model	$B = 7.8498 + 0.0824432 \cdot Vhemisphere$	0.71	8.29	6.17

B: dry biomass (kg); R^2: coefficient of determination; sd: standard deviation; MAE: mean absolute error; * best equation validated with independent data

The high interdependence between the quantity of pruned biomass and diameter at breast height (R^2 =0.87) is probably the result of the pruning practice applied. The crown raising type of pruning is highly dependent from the age of the tree as it is used to give a tree a particular form. It is important to mention that crown raising is introduced in young trees, that have very thin branches. When the tree is older, the lower branches are thicker, therefore the residual biomass obtained by this pruning type in bigger, as in shown by the positive coefficient of the dhb in the Table 10.

The relationship between biomass and crown diameter (R^2 =0.68) can be explained by the fact that crown raising is based on removing the lower braches which are in many cases the oldest and widest ones. Nevertheless, it is important to point that the lower branches do not receive as much light as in the top when the crown is fully developed and therefore these branches will grow more slowly, leading to lack of pruning after a certain age of the tree or to less frequency

CONCLUSIONS

In this work has been found, that significant quantities of lignocellulosic residual biomass with possible energy and industrial end can be obtained from pruning of *Platanus hispanica*, which is one of most important species of Mediterranean areas. For this, three aproaches were followed: Firstly, an statiostical analysis have been carried out; Secondly dendrometric characterization of branches has been carried out. Its objetive was to allow calculating the actual volume of the branches from their base diameter and length.; Finally prediction models based on allometric relationships between dendrometric parameters of the trees and quantity of yielded biomass were developed.

Two techniques have been evaluated to calculate the actual volume of the cut branches from their base diameter and length: using a form factor and volume functions. These, allow calculating the biomass when the branches cannot be weighted or they are in big bundles. It has been verified that volume functions lead to better approximation to the actual volumes than the use of the form factor. When the form factor is used to calculate the actual volume of a branch, the average must be used taking into account big dirpersion that exists in the obtained values. It has been found, that the form factor does not follow a tendency with variation of the base diameter and the length of the branch.

It has been demonstrated that the residual biomass can be predicted from dendrometric variables. In case of *Platanus hispanica* the best explicative variables are diameter at breast height and crown diameter, or the apparent volume of tree crown obtained from conical model, which explain until 87% and 76 % of the population variability respectively. The obtained equations can be used for biomass inventories in urban areas, planning the collection of these residues, and to establish policies for using these materials as feedstock.

Wood moisture content of the pruned wood after cutting is around 50% in wet basis. The variation of moisture content in chips died in free air has been depicted for Mediterranean conditions. This allows predict the days to get determined moisture content. The minimum value is 10%.

The proposed methodology creates the possibility of predicting and quantifying the amount of residual biomass obtained from crown raising pruning operations of *Platanus hispanica* at a high level of accuracy without expensive equipment or labour intensive measurements. It creates a tool to improve the prediction of income, field work and logistics management in the future. Also environmental benefits are indicated such as reduction of carbon dioxide emissions when used as a biofuel, conservation of landfill space, reduction of waste disposal cost and reduction of pressure on forests.

REFERENCES

De La Torre, J. R., 2001. Árboles y arbustos de la España peninsular. Ediciones Mundi-Prensa

Dieguez Aranda U., Barrio Anta M., Castedo Dorado F., Ruiz Gonzalez A. D., Alvarez Taboada M. F., Alvarez Gonzalez J. G., Rojo Alboreca A., 2003. Dendrometria. Ediciones Mundi-Prensa

Drénou C., 2006. La poda de los árboles ornamentales. Ediciones Mundi Prensa

Gil-Albert F., 2001.Las Podas de las especies Arbóreas Ornamentales. Ediciones Mundi-Prensa

Husch B., Beers T.W., Kershaw J. A. Jr., 2003. Forest Mensuration. John Wiley & Sons, INC

López González G. A., 2010. Guía de los árboles y arbustos de la Península Ibérica y Baleares. Ediciones Mundi-Prensa

López Serrano F. R., García Morote F. A., del Cerro Barja A., 2003. Dasometria ciencia de la medición forestal. Popular Libros

MacFarlane D.W., 2007. Quantifying urban saw timber abundance and quality in southeastern Lower Michigan, U.S.A, Arboriculture and Urban Forestry 33(4), 253–263

MacFarlane, D.W., 2009. Potential availability of urban wood biomass in Michigan: Implications for energy production, carbon sequestration and sustainable forest management in the U.S.A. Biomass and bioenergy, 33, 628-634.

McHale, M.R., Burke I.C., Lefsky M.A., Peper P.J.,McPherson E.G. 2009. Urban forest biomass estimates:is it important to use allometric relationships developed specifically for urban trees?Urban Ecosyst 12:95-113

McKeever D.B., Skog K.E., 2003. Urban tree and wood yard residues another wood resource. Research note: FPL-RN-0290, USDA Forest Service, Forest Products Laboratory, Madison, 1-4

McPherson E.G., Simpson J.R., Peper PF, 2005. Municipal forest benefits and costs in five US cities. J For 103:411-416

Michau E., 1987. La poda de los árboles ornamentales. Ediciones Mundi-Prensa

Nyakuengama J.G., Downes G.M., Ng J, 2002. Growth and wood density responses to later-age fertilizer application in Pinus radiate. IAWA Jurnal 23(4):431-448

Pataki D.E., Alig R.J., Fung A.S., Golubiewski N.E., Kennedy C.A., McPherson E.G., Nowak D.J., Pouyat R.V., Lancao P.R., 2006. Urban ecosystems and the North Amercican carbon cycle. Glob Chang Biol 12(11):2091-2102

Pilsbury N. H., Reimer J. L., Thompson R. P., 1998. Tree volume equations for fiftheen urban speciesin California. Technical Report No. 7. Urban Forestry Ecosystems Institute, California´s Polytech State University, San Luis Obispo

Rhoades R.W., Stipes R.J., 1999. Growth of trees on Virginia Tech campus in respons to various factors. J Arobic 25(4):211-217

Sajdak M., Velázquez-Martí B. 2012. Estimation of pruned biomass through the adaptation of classic dendrometry on urban forests: case study of *Sophora japonica*. Renewable energy 47:188-193.

Solid Waste Association of North America, 2002. Successful approaches to recycling urban wood waste. Gen. Tech. Report. FPL-GTR-133, USDA Forest Service, Forest Products Laboratory, Madison, 1-20

Velázquez-Martí B., Fernandez-Gonzalez E., Estornell J., Ruiz L.A. 2010. Dendrometric and dasometric analysis of the bushy biomass in Mediterranean forests. Forest Ecology and Management 259: 875-882

West P.W., 2009. Tree and Forest Measurement. Springer-Verlag Berlin Heidelberg