Estimation of optical porosity or canopy structure of two species of tree with hemispherical and vertical images

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Abstract: Meaningful, reliable and fast estimates of woodland canopy are essential to the characterization of forest ecosystems. In this document, the accuracy of the technology of hemispherical digital photography and its comparison with a measuring proposal via vertically-arranged photography is evaluated for the estimation of canopy porosity in two deciduous tree species: oak and Sweet chestnut. Complementarily, estimative models are proposed of porosity capacity of the species under study, in function of allometric variables of statistical weight in tree growth: canopy diameter and DBH (diameter breast height). For the execution of this study an experimental area of rural character was chosen in the Ambroz Valley, in Cáceres Province (Spain), where *Quercus pyrenaica* and *Castanea sativa* were selected as the most representative species. The data was gathered in the season with greatest foliage development for both species: the summer. The average tree canopy porosity obtained via the two methods under evaluation is very similar when compared through regression analysis (R^2=0,919 for Sweet chestnut; R^2=0,952 for oak). Therefore both methods would be eligible for measuring OP of the species proposed for this study. The equivalence of measurements in vertical perspective as opposed to hemispherical makes viable the use of porosity percentages as indicators of what the average observer is able to visualize through the canopy. Starting from these preliminary conclusions, it would be feasible to develop a quantification tool for degrees of filtering with application to landscape planning and reduction of visual impact. Complementary research on other species could be recommendable in order to standardize and validate this proposal.

Key-Words: Optical Porosity; Vertical forests structure; Allometric relationships; Hemispherical Photography; Vertical Photography; Quercus pyrenaica; Castanea sativa

1 Introduction

1.1. Optical Porosity

Porosity could be defined as the proportion or percentage of pores in space which are occupied by trunk, branches, twigs and leafs of a tree. (Loeffler et al., 1992). It is one of the most important structural characteristics in terms of wind reduction. (Moysey and McPherson, 1966 Hagen and Skidmore, 1971a, Hagen and Skidmore, 1971b, Plate, 1971, Bean et al., 1975). Nevertheless, this variable is hard to define and measure, due to its three-dimensional nature (Zhu et al., 2003).

Many works have tried to simplify this problem by means of a bidimensional metrica of this feature. Thus, parameters arise such as optical porosity (OP), which estimates porosity via measurements of the ground projection in plant of the tree canopy and its gaps (Kenney, 1987, Heisler and DeWalle, 1988).

There are a multitude of concepts which are similar to OP for measuring the phenomenon, so reducing the problem to the projection of the tree canopy on the ground. Thus, among the measurements directly related to OP are to be found Canopy openness (Cop) (Vales and Bunnell, 1988), or the Canopy gap (Cg) (Myers et al., 2000, Yamamoto, 2000), while among the inverse measurements, related to the space occupied by vegetation, are to be found canopy cover (Cco) as the proportion of woodland floor covered by the vertical projection of tree canopy, and canopy closure (Ccl) or canopy density (Cd), as the proportion of hemisphere sky obscured by vegetation when seen from a single point on the ground (Jennings et al., 1999, Korhonen et al., 2006).

However, there is still little information available on the measuring of OP of woodland and the various tree species (Zhu et al., 2003), and its possible application in the field of forest, landscape and leisure management.

1.2. Study of Optical Porosity

There exist several techniques for the study of canopy coverage or optical porosity. So, densitometres and densiometres (Fiala et al., 2006) calculate the percentage of tree coverage by means of estimates of the amount of light or foliage that an observer perceives through these apparatuses, estimating from under the tree canopy, and at distinct points of the same. In general these methods lack accuracy and are subject to a considerable component of subjectivity.

The Cajanus tube is another simple observation method which allows the user to look upwards through a tube which is provided with a leveling system at the top. The user looks vertically through the tube at the image of the crown projected perpendicularly while reflected in a small mirror (placed at an angle of 45 degrees) at the bottom. The whole system is generally placed with assistants. (Johansson 1984, Jennings et al. 1999, Rautiainen et al. 2005; Korhonen et al., 2006). In any case, subjectivity is also present in this method.

Methods intended to minimize the deficiencies are to be found in the use of hemispherical photography (Johanson et al., 1985, Wang et al., 1992, Jennings et al., 1995, Fournier et al., 1996, Rautiainen et al., 2005, Korhonen et al., 2006, Pueschel et al., 2012). To date, these methods are considered to be the most efficient in indirect measurement of OP.

Hemispherical photography is obtained with a camera equipped with a hemispherical lens or “fisheye” arranged horizontally upwards. The photos obtained with this technique provide the researcher with a picture which is apt to determine which parts of the sky are visible and which are obstructed by woodland canopy. It is thus a valuable source of information on position, size, density and distribution of canopy clearings. Hemispherical photography has been used to calculate solar radiation regimes (Montero et al., 2008) and other additional canopy features such as leaf area index, or OP itself.

Hemispherical photographs are treated with image analysis software such as ImageJ© (Image J 1.44 Rasband, 2011) although there also exist “plugins” for commercial image edition software like Adobe Photoshop®. Moreover there is software specifically designed for the analysis of hemispherical photos applied to the study of woodland canopy, namely the Gap Light Analyzer© (GLA 2.0; Frazer and Canham, 1999). Such software facilitate the analysis and processing of a large number of photos.

In spite of the reliability of hemispherical photography in the determination of OP, the simplification of the phenomenon with analysis in ground projection does not evaluate the porosity perceived by the human eye when an average observer places himself in the foreground relative to the trees.

In this sense, few studies have attempted to quantify the degree of OP or its inverse (tree canopy) on vertical planes (Jennings et al. 1999). These works only consider direct ocular estimations, prone, therefore, to the subjectivity of the observer.

Along these lines, in this present work, a measuring method for OP with vertical photography will be developed, for its comparison with the classical method of measurement by hemispherical photography. In this sense, vertical photography can also be analyzed by means of digitalization with image-processing software, as will be detailed later.

The primary aim of this study is to compare the results of the methods of hemispherical and vertical photography (both methods are described in methodology) in estimating a calculation of OP in the trees: *Castanea sativa* and *Quercus pyrenaica.* The aim is to analyze and compare porosity data from different points of view. This aspect has not previously been covered, to our knowledge.

The second aim is to establish estimative models of the capacity for porosity in the species under study throughout their growth cycle, relating the porosity coefficient or concealment obtained with both methods to the variable allometrics of both species.

2. Methodology

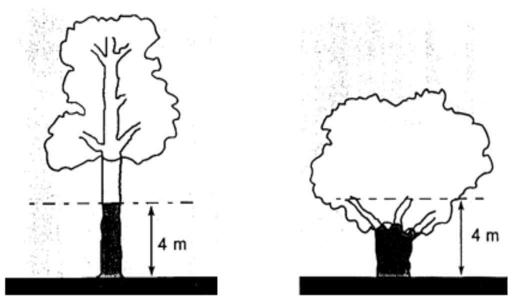
2.1. Characteristics of Species

Vegetation, like every living thing, presents certain genetically defined structural and growth patterns (genotype). But as an element which is part of an environment, it is greatly affected by this: either by abiotic agents like meteorology and physiographic conditions, or by anthropic agents such as human activity. Its vegetative structure may show variations due to the severity of these external actions (phenotype) (Herrera, 1992).

For the development of the study and the choice of experimental plots, a search was carried out for the vegetative structures that were present in great numbers in Spanish context. The National Forest Inventory (ICONA, 1994) provided data on the phenotypes of Sweet chestnut and Pyrenean oak in all the woodlands where these two species were dominant. Thus information was gathered from the Spanish provinces where these two species grow.
The two species which are the object of this research show tree conformations broadly defined according to the growing system in which man has used them.

Both chestnut and oak can be found in Form A, providing they are spindle-shaped trees. These have timber-bearing trunks of 4 meters or more, branching at the top. Another variant is Form B in fruit-bearing production, wherein the main trunk branches are lower than the height of 4 meters. These belong to the group of species mentioned in the National Forest Inventory (ICONA, 1994). (Fig 1).

Fig. 1: The photo on the left is of Form A, while that on the right is of Form B (Source: Third National Forest Inventory). (ICONA, 1994)



The research was completed with data-gathering from young chestnuts and oaks. This provided growth sequencing for each species from youth to maturity in Forms A and B.

2.2. Study Area

The rural research area under study is the municipality of Hervás. It lies at 40º 16' 38" Latitude North and 5º 51' 25" Longitude West in the District of the Ambroz Valley, in the North of Cáceres province, in the foothills of the Gredos and Béjar ranges.

Once the species to be studied had been chosen, as well as their tree architecture and conformation, a search was made for experimental plots which, within the study area, met the criteria laid down.

Data from the Third National Forest Inventory (ICONA, 1994) is used for Forms A and B with the aim of locating places where the trees adapt to the dasometric averages of the trees under study. Ten examples were chosen for each of the tree architectures and species studied: oak in Form A and B, and chestnut in Form A and B. Moreover, a further ten young trees of both species, denominated Form C, were selected in order to complete the research and the series of data from youth to maturity in Forms A and B that means a total of 30 trees under study: 30 for chestnut and 30 for oak. Each tree had its relevant dasocratic measurements taken using a VERTEX Laser Hypsometer (height, branching height, canopy diameter and width of canopy) as well as the UTM coordinates.

Thus, two experimental plots were obtained within the municipality of Hervás for developing the research methodology in rural environments for Form A tree conformations, in both forest species. There were also two experimental plots for studying the selected species in Form B and C tree architecture.

2.3. Methodology of taking photographs

The photos in the research were taken on a CoolPix 995, Nikon digital camera. Four photos were taken for each tree, pointing North, South, East and West. They were always orientated towards the Magnetic North in order to verify the cardinal direction being photographed, and to standardize the field method and subsequent analysis (Valladares, 2006). So as to get the degree of porosity of the trees, the photos were also taken following the two methods below, but using the same camera, for subsequent comparison and standardization of results.

Hemispherical photography

This method allows us to obtain images of the ground projection of the whole canopy. A 180º fish-eye lens is required to generate these images. This must be mounted on a digital camera set horizontally on a tripod at a certain distance above the ground. In this study the height above the ground was 1.5 m. so as to clear the scrub. Also the tripod and camera was set up at 40 cm from the tree trunk, in order to obtain the most complete information about the canopy. Lastly, the photos were taken at times when the sun was not at its zenith, so as to avoid refraction and flares in the pictures taken, which could partially distort the amount of foliage to be analyzed.

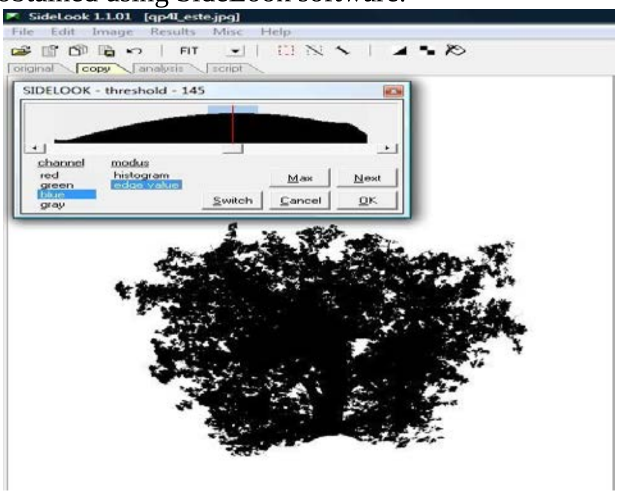
After taking the photos, the next step is to analyze digitally the canopies photographed to work out an average value for the porosity of each tree.

At this point, a quick and simple way of measuring this parameter is by quantifying the number of pixels in the photo which are occupied by foliage.

Fig. 2: Hemispheric photo of a Form A oak to be analyzed with Sidelook (Nobis & Hunziker 2005).

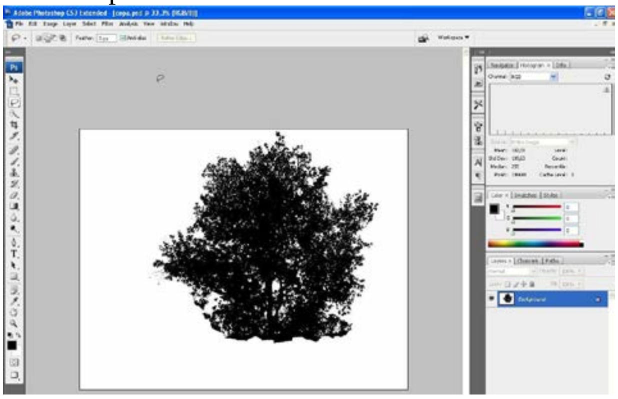
Turning the photos into black and white (negative image) is standard procedure (Montero *et al*., 2008) which facilitates this quantification process. For this step to be as objective as possible, the transformation threshold to black and white cannot be set at random at the whim of the analyst. Generally speaking, this procedure must be standardized to minimize the counting errors. The methodology proposed by Nobis & Hunziker (2005) has been chosen for this reason. The authors prove that the best way to achieve a threshold for converting the photos into black and white is by working in the blue channel of the visible spectrum. Moreover, they have developed software (SideLook v.1.1) which makes this procedure automatic, and which is used in this work for the reasons given. As can be seen in Fig 2 and 3, hemispherical photography gives a ground image of the canopy against a blue background.

Fig. 3: Hemispherical photo in black and white of a oak canopy with south orientation. It can be seen in this photo that, for the purposes of the analysis, the tree trunk has been extracted because we assume that has 100% opacity Transformation threshold obtained using SideLook software.



Once the threshold has been obtained for all canopies of the trees to be studied, the next step is to carry out a count of the pixels in the canopy in each of the four orientations per tree, using the Adobe Photoshop® CS3 computer software (Fig 4).

Fig. 4: Vertical photograph processed with SideLook v1.1. (Nobis & Hunziker 2005), and subsequently analyzed with software Adobe Photoshop® CS3.



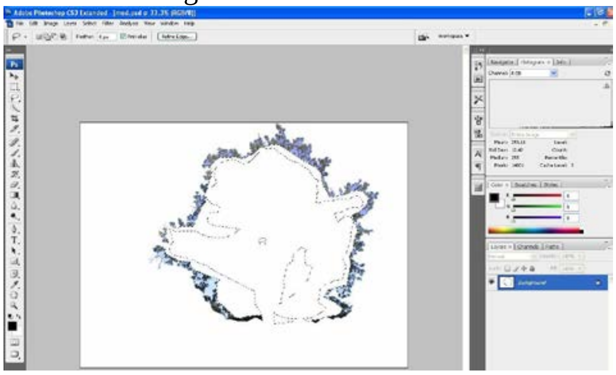
To simplify and speed up the field work, a crop area was performed of the crown against a sky background which is large enough to establish three main zones of porosity:

- Minimum porosity: corresponds to the zones of the canopy with approximately 100% of opacity, usually close to the main trunk.
- Edge porosity: corresponds to the outer zones of the canopy with 30% opacity.
- Medium porosity: these are the zones of the canopy that do not belong either to maximum porosity or to edge porosity.

Once the pixels related to the three types of porosity with sky background have been measured, this information is extrapolated to the rest of the photo and each porosity zone measured is weighted, using the real total area in pixels that each category takes up in the total canopy. To these ends, in the digital process, the same zones mentioned above (minimum, edge and medium) are established for the overall foliage of the tree. Fig 5. shows how the three porosity zones established have been extracted in one of the trees under study.

Each orientation provides three figures corresponding to the three porosity zones established. The porosity coefficient in each one is the weighted sum for the surface occupation of the three porosity zones. The final porosity coefficient of each tree will be finally the average of the four orientations.

Fig. 5: Vertical photograph of a Form B chestnut canopy, with the zones of minimum, edge and medium filtering extracted.



Vertical photography

The decision was taken to contrast the results obtained with the method above by repeating the process with vertical photography. In other words, to attempt to quantify the degree of porosity from other orientations: observing now from the frontal viewpoint of an average observer of 1.70 m. The four cardinal points (N., E., S. and W.) were used again for their best comparison with the cases above, and for their importance from the point of view of the vegetation growth.

The photos taken for this method were taken with the same camera as was used for the hemispherical photos (CoolPix 995, Nikon), at the height of the average observer, on a tripod and at a distance of 10 m. from the tree trunk, so as to capture all the canopies in the study.

As opposed to hemispherical photography, in which the result was a ground image of the canopy against the background of the sky; in vertical photography, the background is often taken up by other trees or objects. This makes it hard to perform an isolated count of the foliage pixels in each study canopy. To avoid photographing this effect, or interference, a white screen was placed during the acquisition of each image.

The screen is set on lengths of PVC tubing at 1.50 m. The maximum height ranged from 8 to 9.5 m, according to the height of the tree canopy. Once unfurled, the screen is 2.40 m. wide by 1.40 m. high. (Fig. 6).

Fig. 6: Vertical photo of Form A oak, taken with screen to block out other trees.

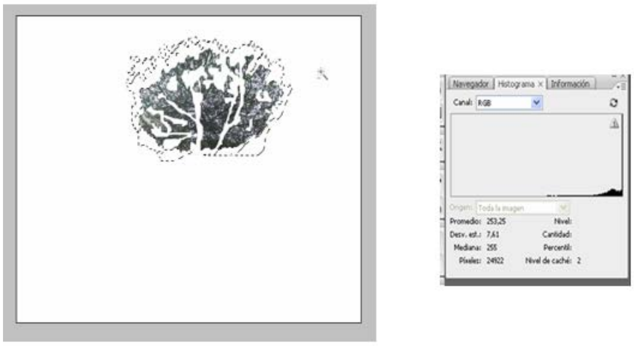
The photos taken in the field are next analyzed using the SideLook v.1.1. software, for transforming into black and white. Then the pixels are counted using Adobe Photoshop® CS3, as explained in the previous method.

As explained in the previous section, to simplify and speed up the field work, the canopy is divided into three main zones of porosity: minimum porosity, edge porosity and medium porosity.

On the other hand, the size of the white screen used does not permit the complete capture of the foliage of each canopy. Therefore, once the pixels related to the three types of porosity with the screen background have been measured, this information is extrapolated to the rest of the photo and each porosity zone measured is weighted, using the real total area in pixels that each category takes up in the total canopy. To these ends, in the digital process, the same zones mentioned above (minimum, edge and medium) are established for the overall foliage of the tree.

This is performed because it is impossible to cover all the canopy with a screen as it would be too tall and wide and utterly unmanageable in the field (it could not be held vertical without sagging; the slightest breeze would bend it like a sail etc). Fig 7. shows how the three porosity zones established have been extracted in one of the trees under study.

Fig. 7: Shows how the three filtering zones established have been extracted in one of the trees under study.



Each orientation provides three figures corresponding to the three porosity zones established. The porosity coefficient in each one is the weighted sum for the surface occupation of the three porosity zones. The final porosity coefficient of each tree will be finally the average of the four orientations, as in the previous method.

Finally for this study, a total of 720 photographs were taken of *Castanea sativa* y *Quercus pyrenaica* in the area of the inventory in the North of Extremadura. The measurements of the degree of canopy obstruction by both methods ranges from 0 (zero obstruction), to 1 (total obstruction)

3. Results

3.1. Sweet chestnut

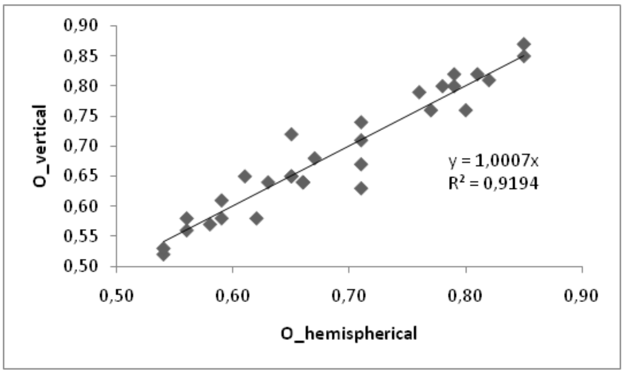
Table 1 shows the treated data for chestnut. For every tree measured, the allometric variables are represented (total height of trunk [Ht], diameter of crown [Dc] and trunk diameter at breast height 1.30 m. [DBH]), and the measurements of the degree of canopy obstruction by both methods (vertical photo or with screen [O_vert], and hemispherical photo [O_hemis]).

Before modelizing the porosity or obstruction versus tree growth, it is important to analyze the advantages of vertical as opposed to hemispherical photography. Using linear regression analysis (Fig 8) the comparison of degree of obstruction is established between hemispherical and vertical photography. This gave similar values with a more than acceptable degree of correlation (R^2=91%). And so it can be stated that the proposed method with screen and vertical photography is valid to measure the degree of obstruction per tree, in this case: chestnut.

Table 1: Data gathered per tree, form and method of acquisition (species: Castanea Sativa). The last two columns show the average obstruction in chestnut canopies for each Method and Type. The degree of obstruction is from 0 (zero obstruction), to 1 (total obstruction).

ID	Form	DBH(cm)	Dc_1(m)	Dc_2(m)	Dc_average(m)	Ht(m)	O_Vert(average)	O_hemis(average)
1	A	14,00	2,70	1,80	2,25	8,50	0,70	0,64
2	A	14,50	4,50	4,80	4,65	8,70	0,71	0,71
3	A	15,00	5,20	5,30	5,25	8,80	0,68	0,56
4	A	18,00	3,90	5,30	4,60	10,20	0,71	0,63
5	A	15,00	4,60	4,50	4,55	8,70	0,71	0,67
6	A	13,75	4,20	5,00	4,60	9,20	0,65	0,72
7	A	13,25	4,70	4,20	4,45	8,80	0,73	0,64
8	A	18,00	5,30	4,90	5,10	8,40	0,72	0,58
9	A	15,75	4,80	5,60	5,20	8,80	0,71	0,74
10	A	19,25	5,10	5,80	5,45	7,50	0,66	0,64
1	B	38,00	11,10	11,10	11,10	9,00	0,79	0,87
2	B	28,00	10,60	10,60	10,60	8,30	0,75	0,81
3	B	46,00	11,50	11,50	11,50	9,30	0,81	0,82
4	B	34,50	10,40	10,40	10,40	11,00	0,79	0,80
5	B	34,25	10,70	10,70	10,70	10,00	0,79	0,85
6	B	30,00	10,40	10,40	10,40	9,40	0,79	0,82
7	B	35,75	10,75	10,75	10,75	11,20	0,77	0,76
8	B	34,50	8,70	8,70	8,70	9,10	0,76	0,79
9	B	32,00	9,80	9,80	9,80	7,60	0,78	0,80
10	B	29,50	5,80	5,80	5,80	6,80	0,80	0,76
1	C	7,00	2,20	3,00	2,60	5,10	0,60	0,52
2	C	7,00	3,30	2,50	2,90	5,40	0,61	0,53
3	C	5,00	2,70	1,60	2,15	3,20	0,58	0,57
4	C	10,50	3,10	2,10	2,60	7,10	0,65	0,65
5	C	11,00	2,00	2,60	2,30	7,70	0,65	0,65
6	C	9,00	4,10	4,20	4,15	7,00	0,67	0,68
7	C	6,00	2,60	2,90	2,75	5,40	0,59	0,61
8	C	7,00	3,60	3,00	3,30	6,00	0,62	0,58
9	C	10,50	2,40	4,20	3,30	6,70	0,61	0,65
10	C	8,00	4,10	3,80	3,95	5,90	0,59	0,58

Fig. 8: Comparison of the degree of obstruction obtained for chestnut with both photographic methods.



The second step is to ascertain which allometric relations carry more weight from the point of view of tree growth, and which ones can be of use to modelize the plant structure.

In this sense, DBH is the variable which most biological importance has had in other works consulted (Montero *et al*., 2008), and it is one of the main variables in this study. The relation of this parameter with the rest of the variables with an acceptable degree of correlation will allow us to forecast the growth of the tree throughout its life. Of all the analyses performed, it is the diameter of the crown which has the closest biometric relationship to the DBH. On the other hand this is to be expected, compared to other parameters such as height – more closely linked to the growth conditions of the mass as a whole (tree density), or forestry activities. Thus, the allometric relationship makes it possible to determine the DBH equation and canopy diameter and reaches the highest percentage of explained variance, giving the best results in model generation (Montero *et al*., 2008), (Fig 9).

Fig. 9: Exponential trend of the allometric variables of significance in the growth of tree canopy of chestnut

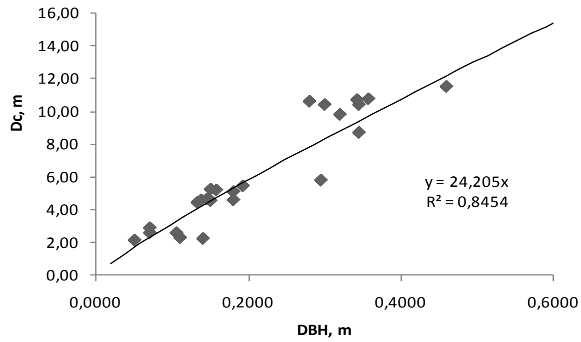
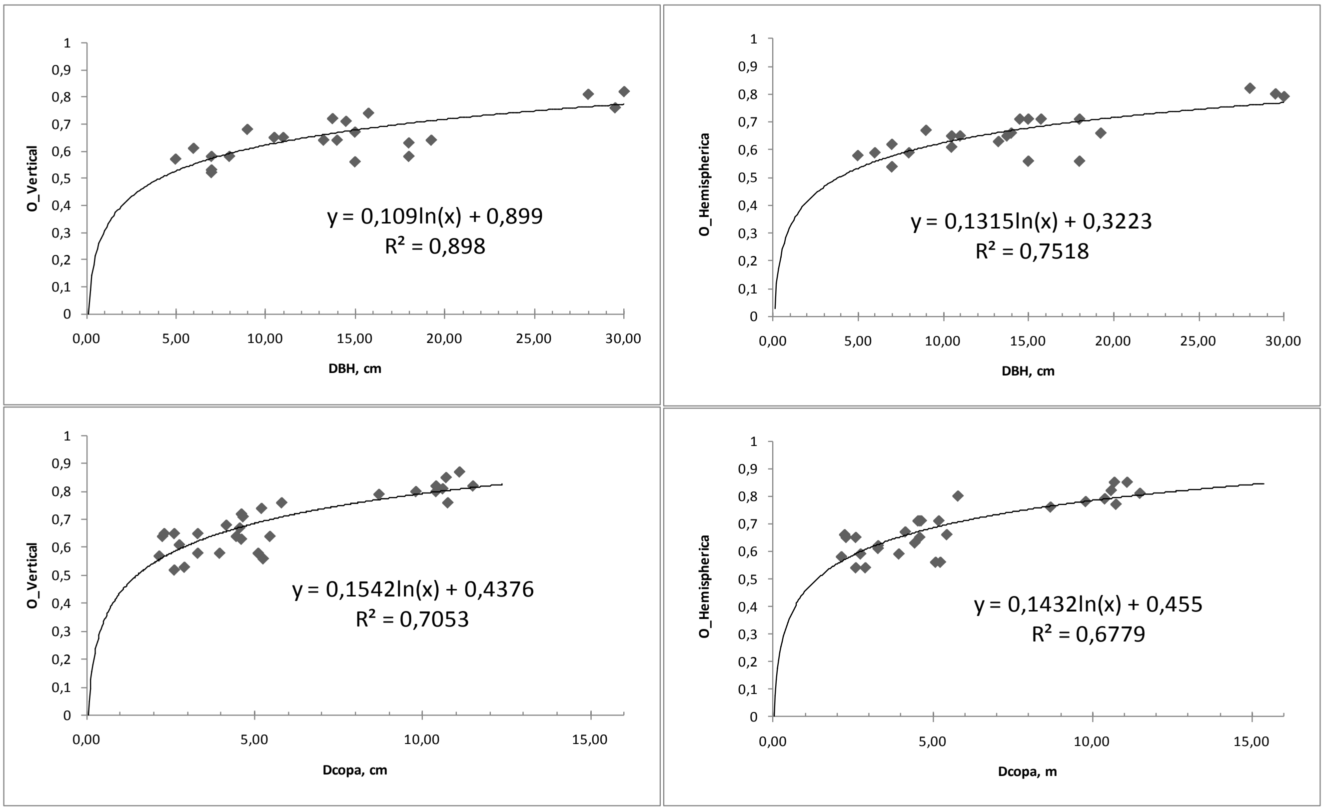


Fig. 10: Logarithmic relationship of the models to estimate the filtering capacity of chestnut, starting from DBH and Dc, for both types of photographic acquisition



Both aspects are therefore the selected parameters from the perspective of obstruction coefficient (or its porosity inverse).

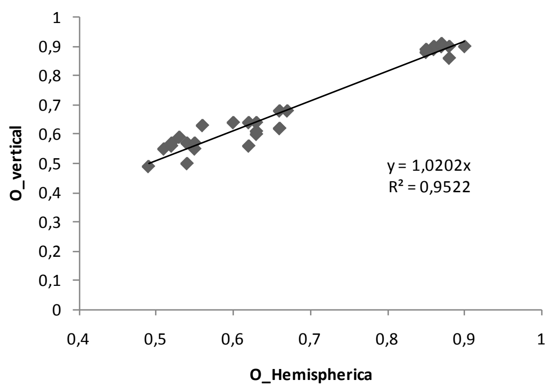
Lastly, the obstruction coefficient of the tree must be studied throughout its growth. To these ends, this coefficient is related to the most significant allometric variables (Dc, DBH) for the two methods of photography, once the validity of both has been established. Thus, by using the non-lineal regression analysis, in Fig 10. it is possible to appreciate the porosity models by growth with the most direct correlation achieved. With these, and with simple biometric measurements in the field (Dc, or even simpler, DBH), it is possible to modelize the amount of porosity that a typical chestnut (under the conditions set for this study) can develop throughout its growth.

3.2. Oak

Using the same protocol set out for the chestnut, in Table 2 the data from allometric variables is appended, in this case for the oak. The Table also contains measurements of degree of obstruction for both methods (hemispherical and vertical).

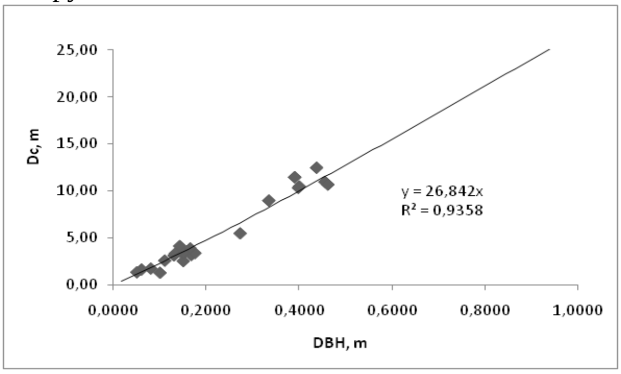
In the validation analysis of the acquisition method for vertical photograph, there has turned out to be a direct link (R^2=95%) (Fig 11) between the data for degree of obstruction for this method and those results for hemispheric photography. Thus, once more, both methods have been shown to be valid, and the methodological proposal is seen to be effective for measuring degree of obstruction.

Fig. 11: Comparison of degree of obstruction obtained for oak with both methods of photography



As was the case for the chestnut, the most significant allometric variables which best explain the modelization of the crown in its growth are the DBH and Dc, as can be appreciated in Fig 12.

Fig. 12: Exponential trend of the allometric variables of significance in the growth of the tree canopy in oak



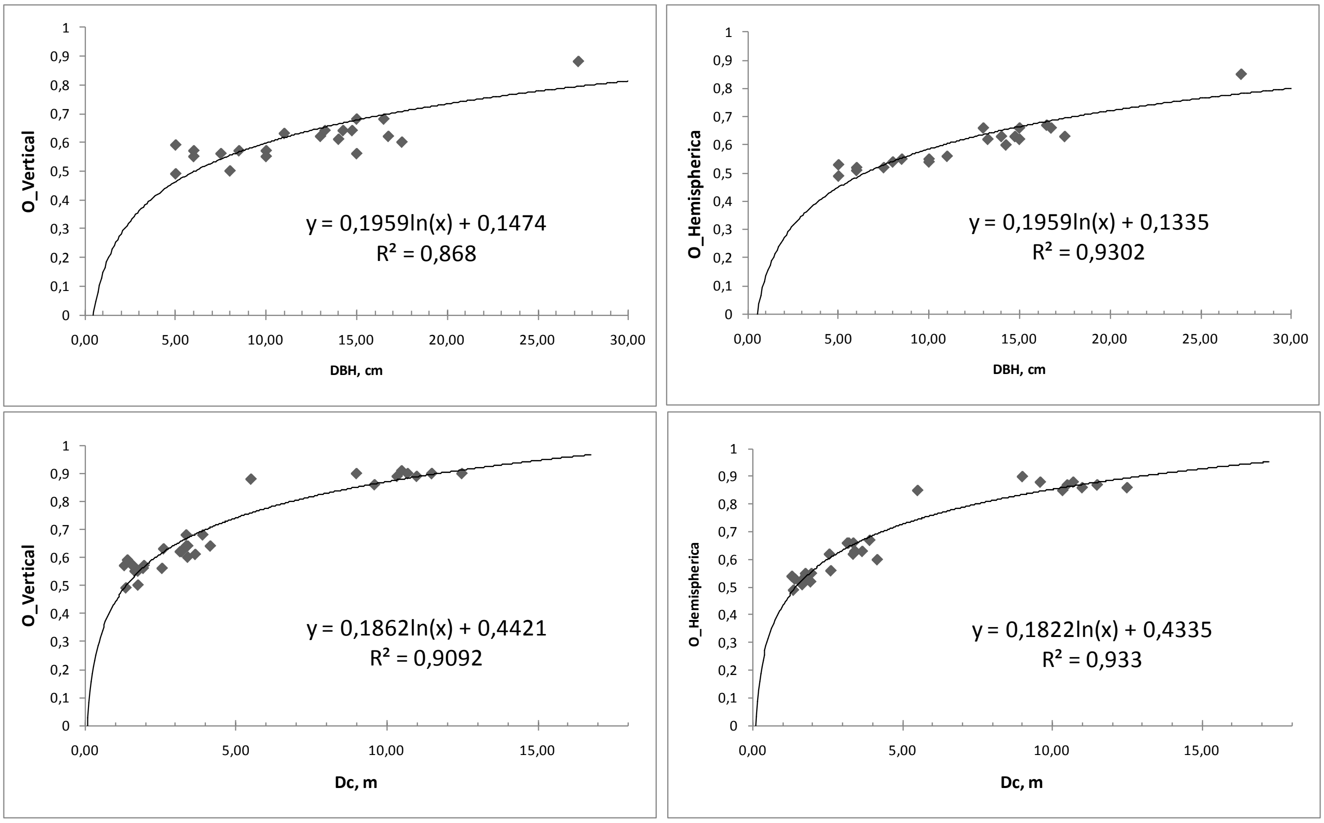
Finally, the predictive model for degree of obstruction with tree growth once more shows a direct correlation for the variables DBH, Dc in both methods of measuring the obstruction (Fig 13). This reinforces the idea of its usefulness in integration research, as was the case with chestnut.

4 Discussion

Hemispherical photography is far easier to take in the field than vertical photography, as well as requiring half as many photos for the subsequent analysis. However, to develop this research it was essential to take vertical photos, since the views obtained of the trees are the same view that an observer of average height sees. This is not the case with hemispherical photography, which gives us a view of the tree canopy seen from below, as explained previously.

In light of the results obtained, among the allometric relationships compiled, the one that relates canopy diameter to trunk diameter (Fig 9. y 12.), is that which reaches the highest percentage of explained variance. Therefore, it is the equation which will give best results in the generation of the obstruction model for the two species.

Fig. 13: Logarithmic relationship of the models to estimate the filtering capacity of chestnut, starting from DBH and Dc, for both types of photographic acquisition



In the light of the results of the statistical analysis established between allometric relationships and the mean canopy concealment in trees under study, Tables 1. and 2. show that the greater the trunk diameter (DBH), the greater the canopy diameter (Dc) of the tree, and consequently the greater is its degree of obstruction (vertical obstruction and horizontal obstruction) and viceversa.

The figures obtained from the statistical analysis of the comparison of the average obstruction of the tree canopy in both methods, which were explained in the previous section, give us the result $R^2=0,919$ for chestnut and $R^2=0,952$ for oak. These results are statistically consistent and they show that both methods make it possible to obtain a similar opacity index, and therefore the protocols set out in the measuring and calculating of this coefficient are validated.

In this study, the results obtained through the analysis performed on the photos by the two methods are very similar. Thus it can be deduced that the two methods would be valid for measuring opacity of *Castanea sativa* and *Quercus pyrenaica.*

The proposed method, based on hemispherical photography for the determination of the degree of obstruction per species has turned out to be consistent enough and easy to utilize to for its use to be recommended in works with similar aims, from the point of view of building landscape integration.
The work of authors such as Rich, (1990), Roxburch & Kelly, (1995) and Valladares (2006), estimate the acquisition of light and its distribution in forestry systems, but they do not calculate the capacity of OP of species. Therefore, these results show an improvement as regards the OP in tree species.

The proposed method based on hemispherical photography for determining the degree of concealment by species has proved to be sufficiently consistent and easy to use to recommend its use in work-related purposes, from the ecological point of view.

Table 2: Data gathered per tree, form and method of acquisition (species: Quercus pyrenaica). The last two columns show the average obstruction in oak canopies for each Method and Type. The degree of obstruction is from 0 (zero obstruction), to 1 (total obstruction).

ID	Form	DBH(cm)	Dc_1(m)	Dc_2(m)	Dc_average(m)	Ht(m)	O_Vert(average)	O_hemis(average)
1	A	14,75	3,10	3,700	3,40	11,50	0,64	0,63
2	A	13,00	2,30	4,00	3,15	11,00	0,62	0,66
3	A	16,75	3,40	3,00	3,20	9,50	0,62	0,66
4	A	15,00	2,80	2,30	2,55	8,30	0,56	0,62
5	A	17,50	3,30	3,50	3,40	9,70	0,60	0,63
6	A	14,00	3,60	3,70	3,65	8,30	0,61	0,63
7	A	14,25	4,30	4,00	4,15	9,80	0,64	0,60
8	A	13,25	2,80	3,90	3,35	9,60	0,64	0,62
9	A	15,00	4,00	2,70	3,35	10,90	0,68	0,66
10	A	16,50	3,80	4,00	3,90	12,70	0,68	0,67
1	B	35,25	9,60	9,60	9,60	9,40	0,86	0,88
2	B	45,50	11,00	11,00	11,00	9,80	0,89	0,86
3	B	27,25	5,50	5,50	5,50	7,60	0,88	0,85
4	B	39,00	11,50	11,50	11,50	7,60	0,90	0,87
5	B	43,70	12,50	12,50	12,50	11,20	0,90	0,86
6	B	40,00	10,50	10,50	10,50	9,60	0,91	0,87
7	B	39,00	11,50	11,50	11,50	10,30	0,90	0,87
8	B	39,78	10,35	10,35	10,35	8,00	0,89	0,85
9	B	33,42	9,00	9,00	9,00	7,70	0,90	0,90
10	B	46,15	10,70	10,70	10,70	10,80	0,90	0,88
1	C	6,00	1,50	1,80	1,65	6,20	0,55	0,51
2	C	5,00	1,40	1,30	1,35	4,20	0,49	0,49
3	C	8,00	1,80	1,70	1,75	6,40	0,50	0,54
4	C	10,00	1,30	1,30	1,30	8,00	0,57	0,54
5	C	11,00	3,10	2,10	2,60	7,00	0,63	0,56
6	C	8,50	2,00	1,90	1,95	5,00	0,57	0,55
7	C	7,50	1,75	2,10	1,93	5,60	0,56	0,52
8	C	5,00	1,40	1,40	1,40	4,20	0,59	0,53
9	C	6,00	2,10	1,05	1,58	5,40	0,57	0,52
10	C	10,00	1,80	1,70	1,75	8,60	0,55	0,55

5 Conclusions

The main conclusions of this work:

1. Both methods are fully valid for measuring the degree of porosity canopy tree species of *Castanea sativa* and *Quercus pyrenaica.*
2. The allometric variable that bears most weight in the modelization of canopy growth (Dc) is the trunk diameter at breast height (DBH). Both variables (Dc, DBH), have had considerable importance in the search for estimative models for the porosity capacity per species in terms of growth
3. These models are a useful tool to analyze the effect that partial obstruction of the tree canopy per species, with direct application in landscape integration studies, as is the case of building integration in the countryside.
4. The simple application of these models means that with the measuring of a single parameter (DBH, or Dc), it is possible to estimate with a high degree of accuracy the obstruction capacity for the species under analysis tree status of growth.
5. Likewise, the consistency of the methodology and protocols laid out here mean that its use is to be recommended in the search for estimative models of porosity capacity in other species than those studied here.

ACKNOWLEDGEMENTS

We would like to thank Ministry of Science and Innovation, for funding Plan Nacional de I+D+I (Project: BIA2007- 61166 “Vegetation as an Integrating Element for Buildings in the Landscape: Methodology and Proposals for Sustainable Town Planning”).

Publication of this article has been possible thanks to the funding of the Ministry for Economy and Competitiveness of Spain and the European Regional Development Fund (ERDF) granted to research project reference CGL2010-19311, as well as the funding of the Government of Extremadura and the European Regional Development Fund (ERDF) (ref. GR15121),granted to the research team in Sustainable Development and Territorial Planning of the University of Extremadura.

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