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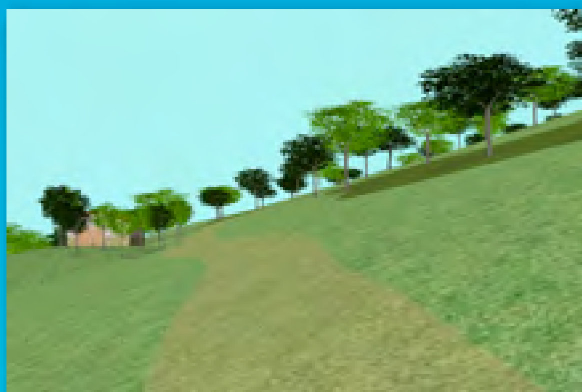
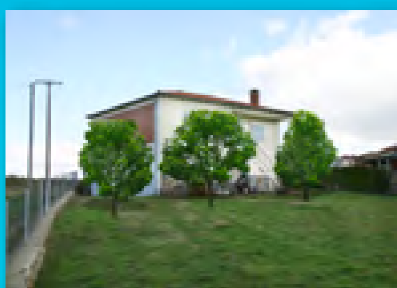
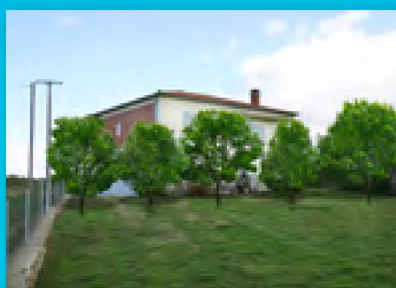
Tesis doctoral

CRITERIOS SOBRE EL EMPLEO DE PANTALLAS DE VEGETACIÓN PARA MITIGAR EL IMPACTO VISUAL DE CONSTRUCCIONES EN EL PAISAJE RURAL







JACINTO GARRIDO VELARDE

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TESIS DOCTORAL

"CRITERIOS SOBRE EL EMPLEO DE PANTALLAS DE VEGETACIÓN PARA MITIGAR EL IMPACTO VISUAL DE CONSTRUCCIONES EN EL PAISAJE RURAL"

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CRITERIOS SOBRE EL EMPLEO DE PANTALLAS DE VEGETACIÓN PARA MITIGAR EL IMPACTO VISUAL DE CONSTRUCCIONES EN EL PAISAJE RURAL

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2014

Jacinto Garrido Velarde

CRITERIOS SOBRE EL EMPLEO DE PANTALLAS DE VEGETACIÓN PARA MITIGAR EL IMPACTO VISUAL DE CONSTRUCCIONES EN EL PAISAJE RURAL

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CRITERIA FOR THE USE OF VEGETATION SCREENS TO LESSEN THE VISUAL IMPACT OF BUILDINGS IN THE LANDSCAPE

2014

de acuerdo con la Mención de Doctorado Europeo

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A mi familia y a todos los que me habéis acompañado en este camino

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"Las ideas son como las estrellas, no llegarás a tocarlas con las manos, pero como el marinero en el desierto de las aguas, las eliges como guía y si las sigues alcanzarás tu destino".

Carl Schurz

INDEX

INDEX

SUMMARY

SUMMARY

The indiscriminate proliferation of new buildings is a real threat to rural heritage and touristic development in areas of great visual beauty. One possible solution is the integration of the buildings in the surrounding environment. So the present research sets variables representative for the modeling and the use of vegetation as a tool for integration of buildings in the environment that surrounds them.

Thus, this research goes deeply into the effect of filtering tree vegetation with dynamic visual studies involving the distance and speed when approaching a building from different points of view. It also discusses the effect the filtering coefficients by species and the arrangement of the trees in space on hiding understood as an integration tool.

The development of methodologies for quantifying impacts based on the digital processing of images, 3D modeling, animation and public participation, are the main working tools for achieving these goals. Thus, a total of 66 scenes, among real photos of buildings and digitally altered ones, were assessed by respondents from different backgrounds and ages.

Among others results, it is highlighting the positive role that the use of vegetation as a filtering, have in the valuation of building integration.

RESUMEN

El problema de la proliferación indiscriminada de nuevas construcciones es una amenaza real al patrimonio rural y al desarrollo turístico en áreas de gran belleza visual. Una posible solución es la integración de las construcciones en el entorno que las rodea. Así el presente trabajo define variables representativas para la modelización y uso de la vegetación como herramienta de integración de las construcciones en el entorno que les acoge.

Este trabajo profundiza en el efecto del filtrado de la vegetación arbórea con estudios visuales dinámicos en los que intervienen la distancia y la velocidad de acercamiento a una edificación desde diferentes puntos de vista. Se analiza el efecto que tienen los coeficientes de filtrado por especie y la disposición de pies en el espacio sobre la ocultación entendida como herramienta de integración.

Además del desarrollo de metodología de cuantificación de impactos basados en el tratamiento digital de imágenes, las principales herramientas de trabajo para la consecución de estos objetivos son: modelización 3D, la animación y la participación pública. Así, un total de 66 escenarios entre fotos de edificaciones reales y modificadas digitalmente, fueron evaluadas por encuestados de distintas procedencias y edades.

Entre otros resultados, destaca el papel positivo que tiene en la valoración de la integración, el filtrado con vegetación.

1. INTRODUCTION

1.1. APPROACH TO THE PROBLEM

The integration of scattered rural buildings in the landscape is a challenge for land-use planning, within the framework of a sustainable territorial model, while at the same time it could be an opportunity for entrepreneurs, particularly in tourism, as it answers a growing social demand and increases the added value of its products (Schmind, 2001; Tassinari *et al*., 2013).

The proliferation of buildings in rural areas, involving the use of architectural typologies far removed from traditional models, has brought about a loss of landscape values in these spaces. Integrating these buildings appropriately in the landscape is an essential step towards preserving landscape quality in rural areas while it also implies having available an essential tool for rural development policies (García *et al*., 2003; Hernández *et al*., 2004).

The visual quality of a built-up area is of importance for its economic and aesthetic connotations. The decisions which modify such an area have a long lasting effect, thus it is fundamental to understand the effects of the changes proposed before carrying them out. One way of doing this is by viewing the modifications via computer simulations in order to assess their impact. (Pullar & Tidey, 2001).

Integration of buildings in the landscape can be achieved by the correct use of parameters inherent to the building itself, such as color, form, line, texture, scale and spatial character, or by means of external factors which may have an significant influence on the above and, as a result, affect the visual integration of the buildings (Smardon, 1979; García *et al.,* 2003; Hernández *et al.,* 2004). One of the most relevant external factors is that of vegetation.

Human activity in a natural setting generates a visual impact. This impact may be reversible or irreversible, positive or negative (Sheppard, 1989; Gómez Orea, 1992; Reyes Rodríguez, 2009). The need to minimize the visual impact of buildings on the landscape is conditioned by society´s growing awareness of environmental respect and conservation which has arisen in recent years (Schmind, 2001; Tassinari *et al*., 2013).

A rural building implies an almost irreversible impact, since the building usually stands for many years; it may be renovated or extended, but rarely demolished (Reyes Rodríguez, 2009). Furthermore, the existing legislation is very vague as to the visual integration of buildings in the landscape. The criteria proposed are not always the best and seldom do they carry out an effective follow-up of legislative compliance. Therefore, one solution is the integration of buildings in the rural landscape, by analyzing the visual relationship between building and setting. Vegetation can be used as a tool to improve the existing visual relationship between building and setting, by means of the use of appropriate vegetative elements to affect the visual elements inherent to the building such as line, form and scale (Hernández *et al*., 2003; García *et al*., 2010)

1.2. VISUAL ELEMENTS OF THE LANDSCAPE

Among the various definitions of the landscape, the existence of a unanimous link, almost exclusively visual, between the landscape and sensorial appreciation (Orejas, 1991), nearly always stands out. This link involves both the observer and what is observed, as well as the environmental conditions interposed between them, generally atmospheric ones with variables of transparency, distance and brightness (Ortega, 1997).

This group of attributes which defines for us the perceived landscape is known as visual elements of the landscape. Its interrelated whole reveals to us the landscape we contemplate from a particular viewpoint. Likewise, the visual aspects of any object, in this particular case isolated building in rural settings, may be defined by their colours, textures, lines and forms, as well as by the references to composition in the scene, such as scale and space for three-dimensional scenarios (Smardon *et al.,* 1979; García *et al.,* 2006, Table 1). These authors aim to break down the landscape scenes belonging to each one.

Table 1. Visual elements of the landscape

	Elements	Characteristics
Superficial Properties	Colour	Shade Saturation Brightness
	Texture	Regularity Density Size of grain Internal contrast
Elements of formation	Line	Sharpness Complexity Direction
	Form	Geometry Complexity Direction
Elements of composition	Space	Composition of the scene Background of the scene Position of units
	Scale	Scene Occupation Scale contrast

This technique based on visual or aesthetic elements to understand the observer's mechanism of perception when contemplating a determined built-up landscape has been studied in depth and used by various authors (Zonneveld & Forman, 1990; Español, 1998; Henderson *et al.,* 1998; Hernández *et al.,* 2004; García *et al.,* 2010).

1.3. VISUALIZATION OF THE LANDSCAPE

Visualizations have been used throughout history for communication between human beings (Bishop & Lange, 2005). Three-dimensional physical models have been used for hundreds or even thousands of years. In the Renaissance, perspective gave widespread importance to drawing and painting, in representing existing or imaginary buildings (Español, 1998; Lange & Hehl-Lange, 2010). In the history of landscape architecture, Repton (1803) can be considered pioneer in the field of landscape visualization (Lange, 2001). In his “Red Books”, he proposed a landscape design perspective representation technique which is not unlike the present day methods.

The appearance in the late 1980s of digital computer visualizations which make it possible to create digital photomontages, and the development and availability of costly software, led to new possibilities for landscape planners. Since then landscape visualization technology has grown significantly, generating many different techniques and methods for this task (Bishop & Lange, 2005).

The method of image draping consists of placing a single image or a combination of images over a 3D terrain representation. Owing to the low complexity of information, this method makes it easy to navigate freely and at high speed in the generated setting. Although it is convenient for an overview of a large area, this method lacks resolution at the viewpoints which are close to the ground (Appleton *et al*., 2002).

Photorealistic representations of vegetation and other landscape features are used for an improved, more realistic simulation of the zone. A high degree of realism is the main benefit of this approach, although the output is not interactive (García *et al*., 2010; Barroso *et al*., 2012).

The virtual reality method (VR) entails totally interactive systems that let the user fly or walk through the composition, obtaining distinct points of view. This approach of VR is similar to a real life experience and gives the users the chance to discover the place rather than just see and contemplate the simulated space (Bishop, 2008). However, the objects are often simplified so as to reduce the time taken for the representation process, and thus realism is lessened and the orientation may be confusing.

In 2001 Lange grouped into three large categories the studies which have helped to boost the research community´s interest in landscape visualization and modeling:

- The first group was focused on “Data Visualization Techniques in Environmental Management” (Orland, 1992).
- The second group appeared shortly after and centered on “Landscape Planning: Increasing the range of tools”. They covered new GIS approaches based on landscape modeling and visualization, and introduced the concepts of cellular automaton and autonomous agents.
- The third group concentrated on “Our visual landscape: analysis, modeling, visualization and protection” (Lange & Bishop, 2001). It dealt with landscape assessment, GIS modelling, visual representation and the questions of perception in the representation of digital landscape. (Bishop *et al.*, 2001; Danahy, 2001; Lange, 2001; Sheppard, 2001).

1.3.1. 3D VISUALIZATION

Over the last few decades contemporary Western society has changed from a world dominated by digital immigrants to a worldwide professional society dominated by digital natives (Lange, 2011). The tools and technique to represent our world in 3D visualization have spread into our everyday lives. Babies in the womb can be seen in 3D echo graphs. Children, parents and even some grandparents play with 3D video games. Soon we will be watching TV in 3D and 4D multisensory cinema. Google Earth software means we can navigate and explore remote regions in perspective views thanks to the data transmitted via internet (Sheppard & Cizek, 2009) which shows 3D representations of the landscape with a wide range of textual information (Lange, 2011).

Currently visual representation techniques have become a common research tool, whereas they were only used sporadically in previous decades. The physical models, drawings and images have quickly evolved into virtual realities and visualizations based on Internet (Lange, 2011).

3D landscape visualizations have evolved from their beginnings, which required costly technology and specialized equipment, into 3D visualizations using free programmes (Google Earth) using non-specialist equipment (basic computer skills). Also within the last few decades, digital landscape representations have gone from abstract, static ones to realistic visualizations which can be explored by dynamic spatial movement. This offers the potential of an immersion experience in multiple spatial and temporal scales. Computer-generated 3D models can be seen from all angles and let the viewer visually experience an environment yet to be constructed (Conniff *et al.*, 2010). Technological advances mean that it is increasingly easy and fast to sketch out a design and finalize details with the applications of assorted software.

Gosling in 1993 and Conniff in 2010 recognized the potential value and the importance of presenting respondents with proposals for “strolls” through an urban design. Some researchers have questioned the perception of the environment on static images (photographs) when we normally experience the world around us via a flow of changing visual images. Though the scientific community accepts that photographs evoke responses similar to those felt when really in the location represented (García *et al.*, 2010, Barroso *et al.*, 2012), Heft & Nasar (2000) found that reactions to static screens are not the same as those to screens in motion. These authors found that the respondents’ preferences were significantly less when comparing static scenes and ones in motion. This finding has implications as to how to present people with the designs, since a building and the setting which houses it may appear attractive in a drawing or computer-assisted design model (CAD), but we do not usually observe a building statically. Therefore it could be argued that video presentations of future settings probably conjure up perceptions and reactions which are closer to what we come across in the real world, in detriment to those evoked by static images (Conniff *et al.*, 2010).

The use of digital representations based on digital or virtual settings is well established in planning and has become a common feature in landscape and town planning. Nevertheless few studies have been found about the fact that visualizations can also fulfill a purpose of internal communication between experts of different disciplines, or within the same one, who are working on a shared project. Regarding the contents, landscape visualizations are still usually centered on the final product of a process of planning and design, whose aim is to communicate with the public or potential clients (Lange, 2011).

1.3.2. TOOLS FOR LANDSCAPE VISUALIZATION: GIS AND CAD

A large part of the data required to generate a 3D model can be managed within a GIS. These contain a large analytical capacity which is often used to test and assess planning criteria (Pullar & Tidey, 2001).

In practice, GIS are used as a decision-making tool in town planning due to their large capacity for storing a wide range of information in their spatial database available at the various aggregation levels, such as parks, car parks, the footprint of buildings, transport network data…

The logical data model in GIS gives a codified representation of the features of the real world in terms of their geo-referenced location, spatial extension, spatial connectivity, attribute properties and the compositional relationship with other characteristics. GIS have always had a strong link with database technology and therefore the representation of the knowledge of a wide range of spatial information. GIS provides multiple visual and analytical interpretations of the information as well as a large amount of functionalities to explore the data.

3D visualization systems are more closely linked to CAD systems. These systems are usually used for the construction and visualization in 3D of environmental design data which are used in engineering. Functionality in CAD is oriented towards graphics measurement and generation for a single visual perspective. This often implies very complex representations of 3D graphic forms and parametrical surfaces, rather than creating superior abstract models of the spatial phenomena. CAD systems are similar to 3D visualization systems, since they are optimized for graphic visualization of the 3D perspective (Pullar & Tidey, 2001).

Design planners and professionals need a 3D visualization interface with which to interact with the landscape and the built-up environment, including data of terrain, of buildings (façades and roofs), thoroughfares, pavements, traffic signs, parks and trees (Ranzinger & Gleixner, 1997). Landscape is stored in a GIS as digital terrain model (MDT), in which, by means of the draping technique, it is possible to incorporate the features of the shape of the relief (Appleton *et al*., 2002). The objects of the surroundings constructed in 3D can be generated from 2D characteristics by using the appropriate parameters on a GIS. The punctual characteristics represented by electricity pylons can be generated from the database attributes. Trees of various heights, shapes, densities, colours and textures are created in a 3D model. In GIS systems the buildings can be extruded using the attribute of building height. To give the scenic composition greater realism textures originating in photos of the buildings are used (Hoinkes & Lange, 1995).

Some users may wish to navigate freely in a 3D space while others may prefer to digitalize a path (Danahy & Hoinkes, 1995). In many cases, the interaction with the design will switch between a 2D representation of the map and a 3D scenic representation. Manipulation of any kind must have a purpose, and this demands analytical functions to indicate how this purpose is being fulfilled. The design factors can be expressed in terms of spatial suitability for certain activities, or for the localization of design elements (Pullar & Tidey, 2001).

GIS software has developed elements for handling and assessment on decision-taking for an urban design proposal. However, further research is needed to understand design criteria for 3D scenes. A GIS can be used to find important observation points such as streets, paths and visual corridors and to visualize these strategic points within a localized scene. The visualizations generated by computer in 2D or 3D represent a abstracted graphic view or a new proposal of the real world (Pullar & Tidey, 2001).

1.4. PLANT SCREENS

A way to integrate the buildings in their setting is by creating plant screens to partially or entirely conceal the buildings (Smardon, 1988). Furthermore, plant screens reduce the scenic occupation of any building, particularly when the building is visible almost in its entirety, or when the plant screens are laid out in the foreground of the building, which means that the scale is perceived to a lesser extent, so softening any possible negative impact. Occupation of the whole scene is hard to measure from the visual viewpoint since the overall scenic composition of what is observed so not always taken in at a single time. However it is possible to fix this characteristic by fixing the frame and distance of observation, by means of photographic analysis (Stewart *et al.,* 1984; Hull & Stewart, 1992; Montero, 2008a; García *et al.,* 2010).

Furthermore, and regarding scale, the relative comparison of building volume with the scale of adjacent elements (trees and bushes) means that that the building heights are not contrasted with the setting, and so its presence has less of an impact (Zacharias, 1999).

Lewis (1999) highlights the possibility of total concealing the building by means of vegetation screens, when, owing to the formal and composition features of the building, it is impossible to achieve good integration in the landscape. Total concealment of said buildings is not necessarily the best solution. In some cases, partial concealment may be preferable, to give a result of variation in the visual characteristics of the building, in such a way that their form, line or scale of the same are modified by the vegetation, thus resulting in better integration in the setting (Jaeger & Reffey, 1992; Bishop *et al*., 2001).

Sharpness depends on line length as well as on their saturation. According to the values taken by these two variables, they can give: sharp, intermediate or insinuated lines. The greater the difference between the lines of the surroundings and those of the building, the greater the contrasts will be. Surroundings in general do not give intermediate lines, and buildings tend to present sharp lines. When vegetation is introduced that partially conceals the buildings, it is possible to pass from those sharp lines forming the buildings to intermediate ones (since the vegetation means that we perceive these lines with less length and saturation, and this fact reduces their sharpness). As a result the “leap” in sharpness between the lines that make up the surroundings and those of the rural buildings is reduced. Consequently, the contrasts are also reduced (Smardon, 1986; Español, 1998; García *et al.,* 2010).

Geometry refers to the greater or lesser regularity in the elements which compose the scene. Buildings tend to introduce very regular prismatic forms into the surroundings, which may provoke contrasts with the generally irregular forms of the elements making up the natural landscape (Oppenheimer, 1986; Berezovskaya *et al.,* 1997). The vegetation is intended to hide the very defined form of the buildings, so producing a certain sense of irregularity, and by these means diminishing the contrasts.

The predominant orientation of the lines that make up the surroundings is horizontal. The buildings introduce isolated vertical lines that may give rise to contrasts. The introduction of vegetation leads to the inclusion in the scene of new reference elements which harmonize the whole with their verticality, so reducing these contrasts (García *et al*., 2010).

The less the complexity in the form of the buildings (these are basically composed of simple, regular forms which easily draw the perceiver’s attention within a setting of irregular forms), the greater are the contrasts introduced in relation to the surroundings composed of complex forms. Plant barriers hide the simplicity of the building’s form. The introduction of vegetation which partially hides the straightness of the lines composing the buildings implies that a certain degree of complexity is added to the lines making up the landscape, so reducing the scene contrasts (Karjalainen & Komulainen, 1999).

The addition of natural vegetation elements, whose forms display orientation similar to that of the building, achieves better integration of the latter in the surroundings by reducing the contrasts.

The way to integrate the lines and forms of the buildings, in such a way as to achieve greater harmony in the landscape, will be to include vegetation elements on the building edges. The barriers will be of appropriate size and foliage density to partially conceal lines and forms (Muhar, 2001). Furthermore and if it should be necessary, the plant screens will be suitably staggered, by using tree and bush species native to the area and of varying size, foliage densities and rates of growth (Purcell & Lamb, 1998). These screens are to be placed in front of the edges or also behind them, as is the case with the ends of the building. This will prevent the cut-out effect against the skyline.

But the vegetation itself has not always been studied explicitly, but rather indirectly via related concepts such as the “Mystery”. The concept can be understood as the degree in which an observer can get more information from a scene if he could penetrate it (Kaplan & Kaplan, 1989; Stamps, 2004; Ikemi, 2005). Thus an activity is seen as more or less concealed, the degree of mystery of the scene increases with the observer’s need to obtain more information from it. Recent works include the vegetation element and they relate it directly with the concept of mystery, as an attribute which is vital to take into account within the visual scale the landscape is observed from (Tveit *et al.*, 2006; Tveit, 2009).

Visual scale is a concept which stands out in the theories concerning landscape preferences and visual quality. This concept deals with experience of perception of the landscape units: size, form and diversity. Scale is affected by the line of vision and the visible area and is related to the size of grain and the degree of openness in the landscape. The degree of openness is directly related to the landscape preferences (Hanyu, 2000; Clay & Smidt, 2004).

1.5. OBJECTIVES

Any building set in a natural environment generates visual impact. The use of vegetation is an effective concealment tool when the impact of the building is higher than is desirable. However, a means of harmonization is fundamental since it can guarantee a better relationship between built space and the setting, and contribute towards the creation of quality managed landscapes. For the aforementioned reasons, the scientific and technical objectives of this thesis are as follows:

1. The main objective of this thesis is to obtain criteria for the use of vegetation screens to lessen the visual impact of buildings in the landscape.

This objective is complemented with other specific objectives, which refer to filtering, arrangement, density of vegetation used as screen to integrate the building in its surroundings, and which, to sum up, contribute to the achievement of the main objective. They are as follows:

2. To compare the results of hemispherical and vertical photography in order to estimate the calculation of optical porosity in the trees: *Castanea sativa* and *Quercus pyrenaica*. The aim of this is to analyze and compare porosity data from various viewpoints. It also aims to establish estimative models for the porosity capacity of the species under study throughout their growth, relating the porosity or concealment coefficient obtained with both methods against the allometric variables of the two species. (Compliance with these objectives has been dealt with in paragraphs 2.1. and 3.1.).

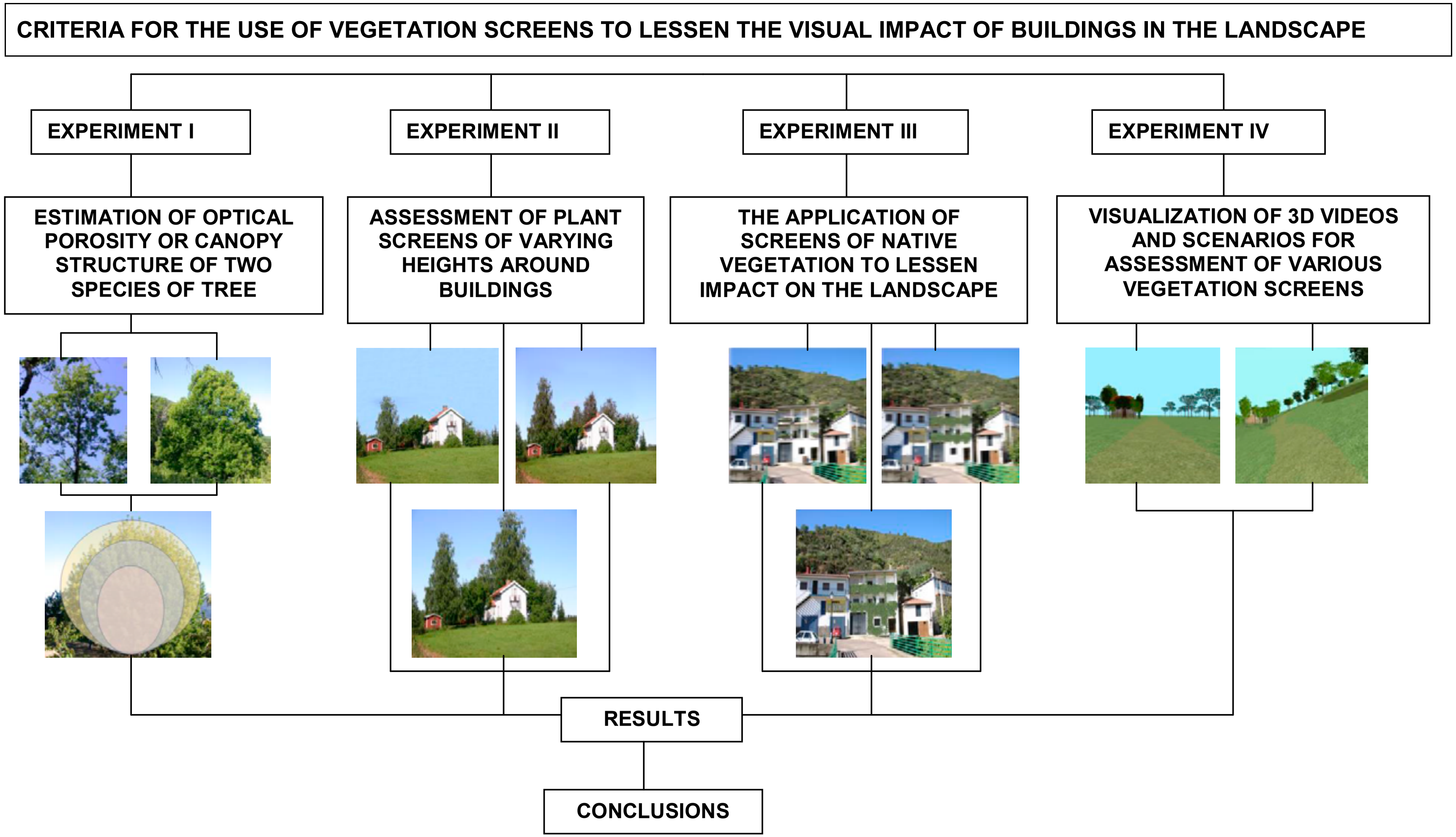
3. To assess the effect of the application of different vegetation scales over the same building; this will tell us the right scale of vegetation to be used as landscape integration tool for the various buildings. This aims to minimize the visual impact generated by the buildings within the natural esthetics of a rural setting. The objective of this experiment is to assess distinct heights of vegetation screens around the buildings in order to improve their integration in the landscape. To these ends, species and buildings have been selected for study from the Ambroz valley, in the north of Cáceres (Spain) and in the region of Norrland in the north of Sweden. (Compliance with these objectives is dealt with in paragraphs 2.2. and 3.2.).

4. To detect how the variation in percentages of concealment by vegetation screen can affect visual perception and the assessment of the same in the immediate surroundings. In order to achieve this objective, digital image analysis techniques starting from real images are used, along with

scenario simulation. Various practical cases gathered in the north-west of Spain are used for this purpose. Distinct filtering percentages with different vegetation types are simulated in these initial buildings. (Compliance with these objectives is dealt with in 2.3. and 3.3.).

5. To go in greater depth into the effect that vegetation screens have on the integration of buildings in the landscape, using new 3D visualization techniques, videos and public participation. To these ends, the “status quo” of two study zones of coastal and inland Spain has been modeled, placing vegetation screens around a type building, varying their density, species and layout. Once a series of scenarios were established, videos were generated at different speeds to simulate touristic activities that can be carried out in the open air. The aim is to analyze how movement affects perception of the building-vegetation screen as a whole, in its various versions. (Compliance with these objectives is dealt with in 2.4. and 3.4.).

1.6. GRAPHIC SCHEME FOR THE DEVELOPMENT OF THE THESIS



2. MATERIALS AND METHODS

2.1. EXPERIMENT I: ESTIMATION OF OPTICAL POROSITY OR CANOPY STRUCTURE OF TWO SPECIES OF TREE WITH HEMISPHERICAL AND VERTICAL IMAGES

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 & McPherson, 1966; Hagen & Skidmore, 1971a; Hagen & Skidmore, 1971b; Bean *et al.*, 1975). Nevertheless, this variable is hard to define and measure, due to its three-dimensional nature (Zhu *et al*., 2003).

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.

Methods intended to minimize the deficiencies are to be found in the use of hemispherical photography (Johansson, 1985; Wang *et al*., 1992; Jennings *et al*., 1999; 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 optical porosity (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*., 2008b) 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 CS5 ®. 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 & 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 experiment, a measuring method for OP with vertical photography will be developed, for its comparison with the classical method of measurement by hemispherical photography.

2.1.1. DETERMINING FACTORS OF THE 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 Third 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 (Figure 1).

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). (Figure 1).

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.

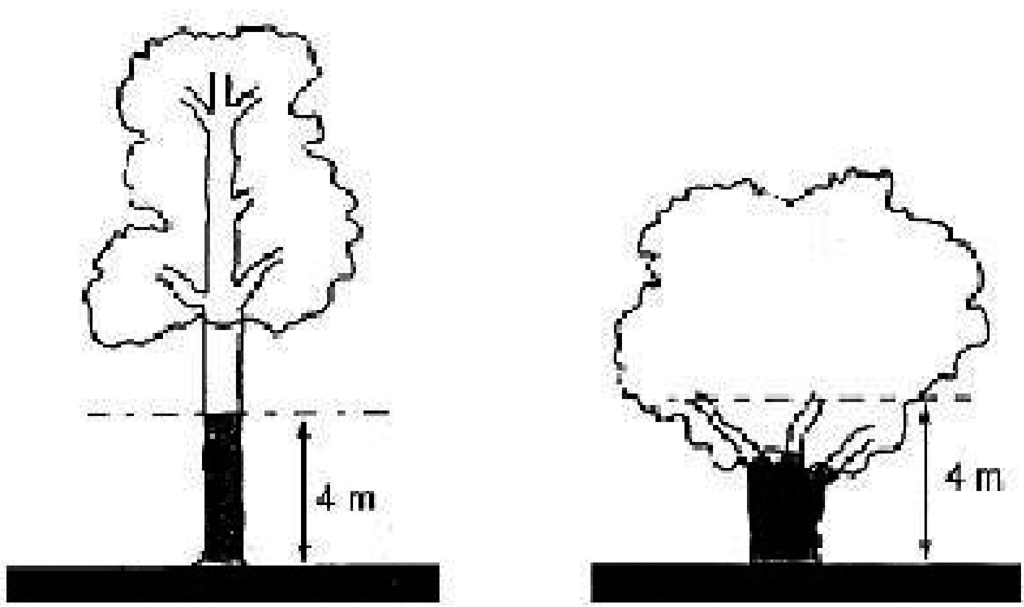


Figure 1. The photo on the left is of Form A, while that on the right is of Form B (Source: Third National Forest Inventory). (ICONA, 1994)

2.1.2. RESEARCH AREA: MUNICIPALITY OF HERVÁS

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.

2.1.3. PHOTOGRAPHY IN THE FIELD

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 filtering 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.

2.1.3.1. METHOD 1: 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 filtering 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. Turning the photos into black and white (negative image) is standard procedure (Montero *et al*., 2008b) 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 figures 2 and 3, hemispherical photography gives a ground image of the canopy against a blue background.

Figure 2. Hemispheric photo of a Form A oak to be analyzed with Sidelook v.1.1 (Nobis & Hunziker 2005).

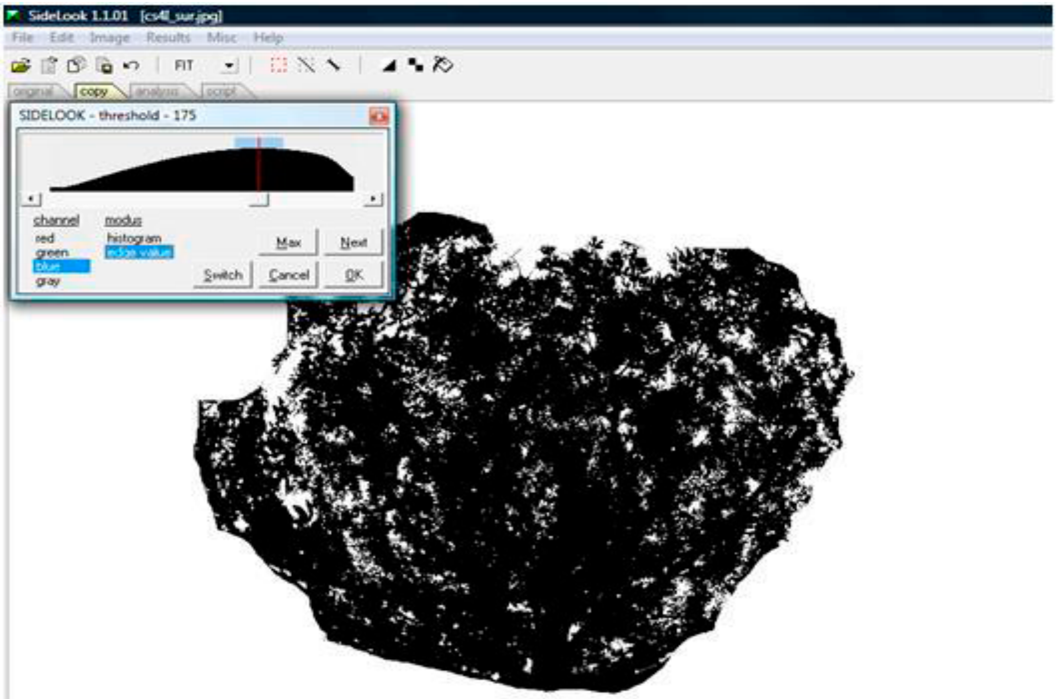


Figure 3. Hemispherical photo in black and white of a oak canopy with south orientation. It can be seen in this photo that, for the purposes of the analysis, the tree trunk has been extracted because we assume that has 100% opacity transformation threshold obtained using SideLook v.1.1. software.

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 CS5 ® computer programme (Figure 4).

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 filtering:

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

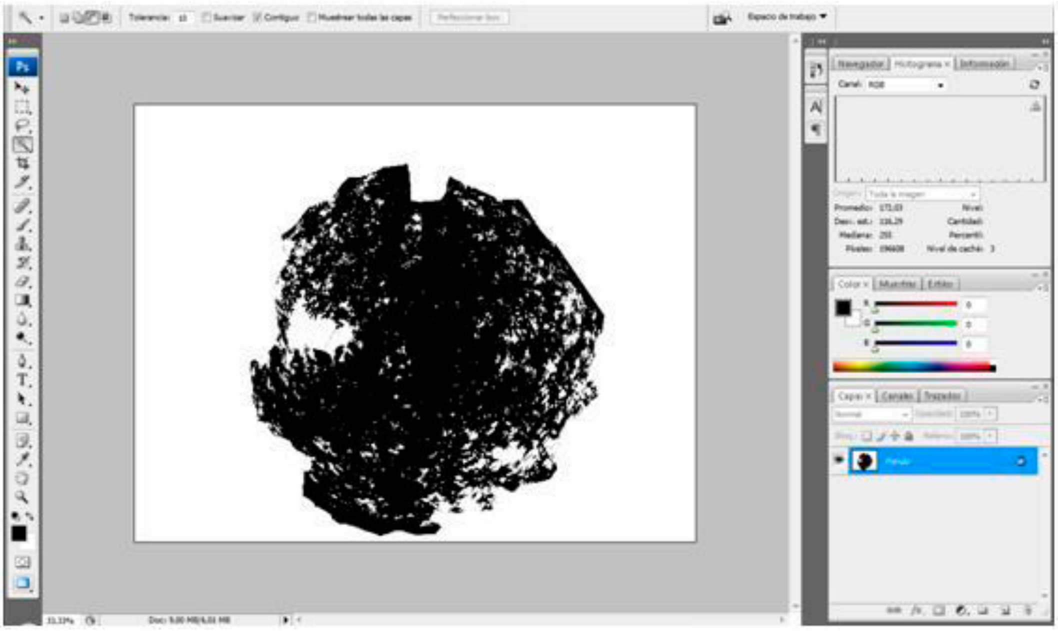


Figure 4. Vertical photograph processed with SideLook v1.1. (Nobis & Hunziker, 2005), and subsequently analyzed with software Adobe Photoshop CS5 ®.

Once the pixels related to the three types of filtering with sky background have been measured, this information is extrapolated to the rest of the photo and each filtering 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. Figure 5 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 filtering zones established. The filtering coefficient in each one is the weighted sum for the surface occupation of the three filtering zones. The final filtering coefficient of each tree will be finally the average of the four orientations.

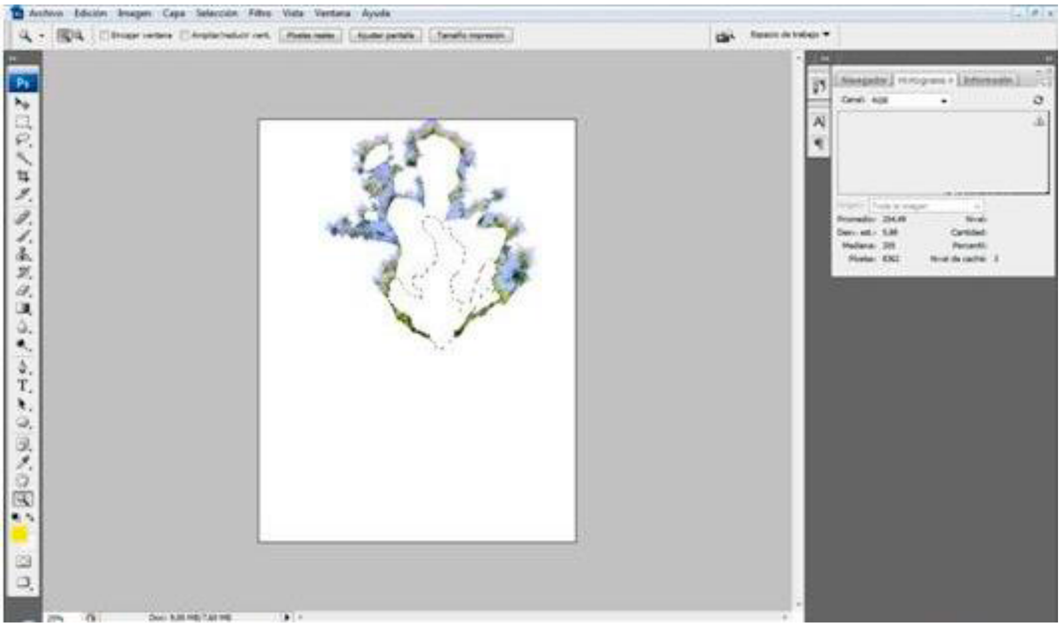


Figure 5. Vertical photograph of a Form B chestnut canopy, with the zones of minimum, edge and medium filtering extracted

2.1.3.2. METHOD 2: 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 filtering 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 (Figure 6).

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 CS5 ®, as explained in the previous method.

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

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

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 filtering with the screen background have been measured, this information is extrapolated to the rest of the photo and each filtering 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). Figure 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 filtering zones established. The filtering coefficient in each one is the weighted sum for the surface occupation of the three filtering zones. The final filtering coefficient of each tree will be finally the average of the four orientations, as in the previous method.

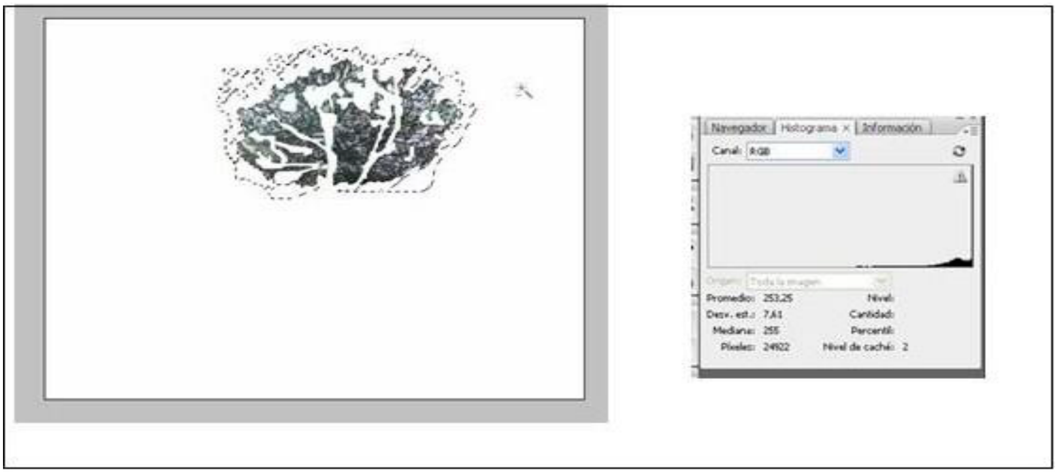


Figure 7. Shows how the three filtering zones established have been extracted in one of the trees under study

2.2. EXPERIMENT II: ASSESSMENT OF PLANT SCREENS OF VARYING HEIGHTS AROUND BUILDINGS TO IMPROVE THEIR INTEGRATION IN THE LANDSCAPE

The chief objective of this experiment is to assess various heights of plant screen around buildings in order to improve their integration in the landscape. To these ends, the species and buildings which are the object of study are those to be found in the Ambroz Valley, in the north of Cáceres (Spain) and those found in the region of Norrland, in the north of Sweden.

2.2.1. AMBROZ VALLEY STUDY AREA

The rural experimental area for the study is the Ambroz Valley district, in the north of Cáceres Province and in the foothills of the Sierra de Gredos and Béjar mountains (Figure 8).

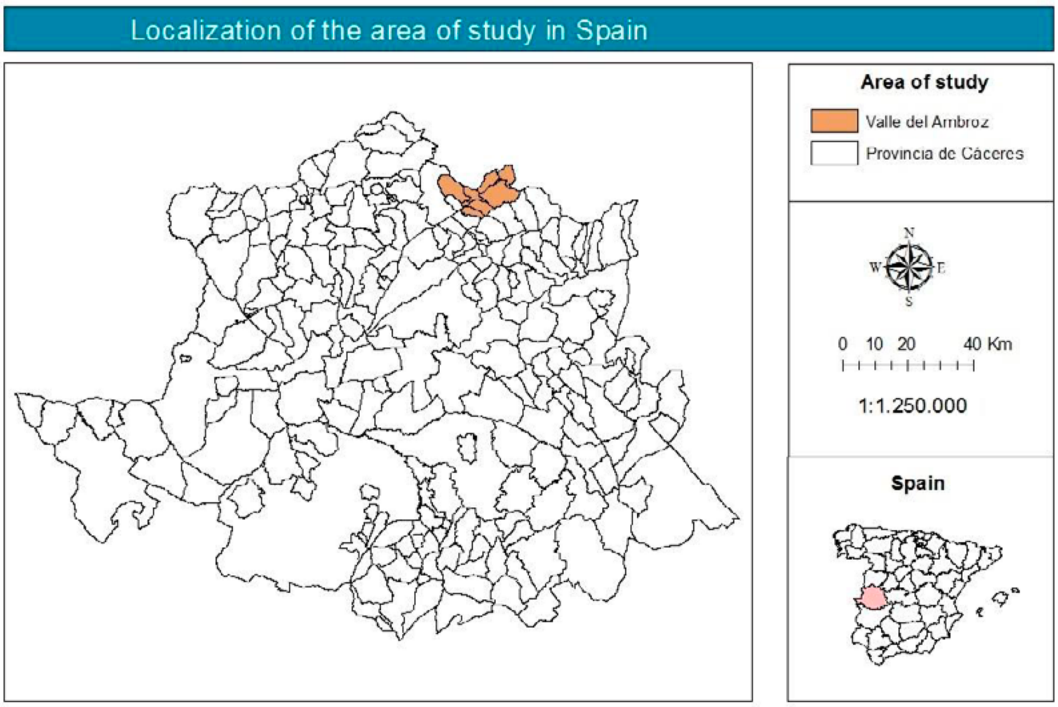


Figure 8. Location of the Ambroz Valle district experimental area, in the north of Cáceres

In terms of physical environment, the Amboz Valley presents a natural diversity of high quality due to the range of altitude, from 400 metres to 2102 metres, the summit of Pico Pinajarro. Thus it provides the optimal growing conditions for sustainable, mature woodland.

The woodland systems to be found in the Ambroz valley are, from higher to lower altitude:

- High mountain woodland, which on account of the climatic conditions shares its environment with heathland, cytisus spp, brooms, high mountain grazing land, moss, lichen etc.
- Atlantic woodland, deciduous and rich in vegetation, including sweet chestnut, oak, holly, yew, etc,
- Mediterranean woodland, consisting of holm oak and old cork oak woods, cultivated areas and irrigated flat valley bottoms.

After the characterization of the vegetation in the study area, the next step was to visit in the field the various defined buildings and woodland masses in order to check the characteristics, both natural and in building terms in the Ambroz valley, in order to select buildings in the natural environment for the development of the methodology of this research project.

Vegetation, like all biological elements, presents structural and growth patterns which are defined genetically (genotype). But as an element which is part of the environment, it is strongly influenced by it. Either due to abiotic agents, such as meteorology and physiographic conditions, or due to anthropic agents, as is the case with human activity, its vegetative structure may show variations in the severity of these external actions (phenotype) (Herrera, 1992).

The combination of constructed and vegetative experimental structures was searched for, which is largely to be found in the whole experimental area of the Ambroz Valley. Each building and vegetative element within a scenic composition was measured as required with the VERTEX Laser Hypsometer (height of building, height of adjoining vegetation) as well as UTM coordinates (Figure 9).

Figure 9. Typical building in the Ambroz Valley

2.2.2. STUDY AREA IN SWEDEN

In the area chosen for the project, the vegetation is based on the dominance of mixed transitional woodlands which gives way to taiga. These require a milder climate and soil that is unfrozen most of the year, always accompanied by undergrowth of grasses, ferns and moss. Here the dominant species are sessile oak (*Quercus petraea*), on its northernmost boundary, and norway spruce (*Picea abies*) at its southern limit, both intermixed with scots pine (*Pinus sylvestris*) in the driest areas.

Following the guidelines used for the selection of vegetation and building type which are to be studied in Spain, a search was carried out for the combined structures of experimental building and vegetation which are mostly to be found in the experimental region of Norrland, in northern Sweden (Figure 10), taking only the buildings which complied with the typical construction characteristics of Sweden. The same protocol of height measurement and UTM coordinate taking was performed in the Swedish scenes.

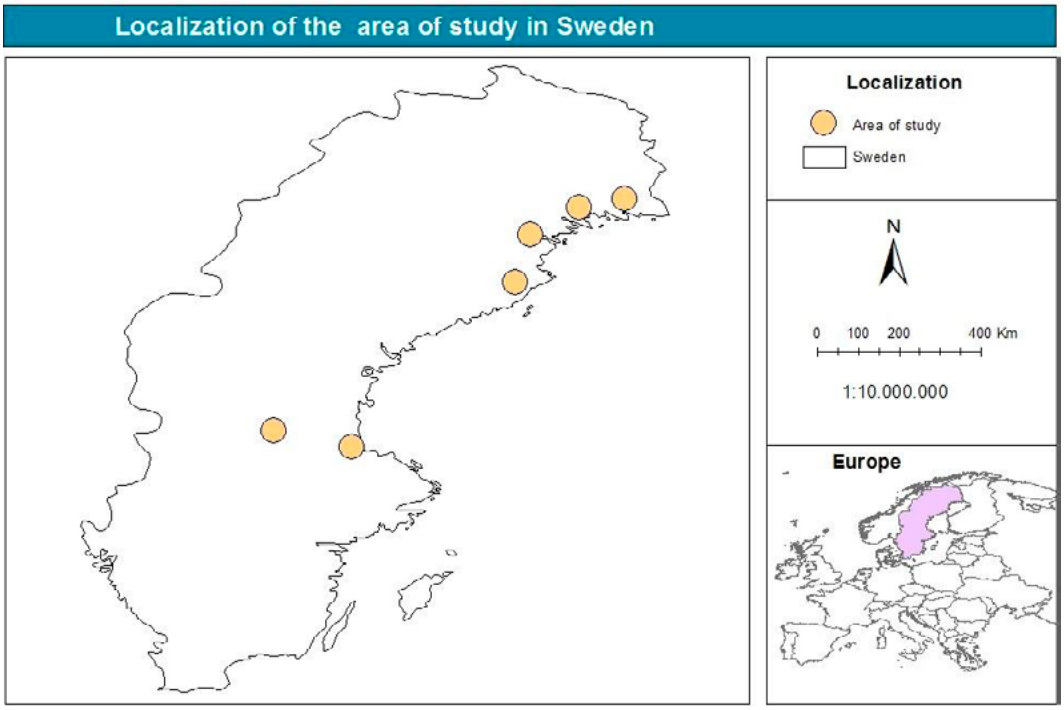


Figure 10. Location of study objects with traditional buildings in Sweden.

2.2.3. PHOTO CAPTURE (1)

Although some authors question the validity of the photographic method and express certain doubts as to whether a photo can represent a complex scene or whether it can reliably evaluate attributes in studio which are not perceptible via photo, such as sound, smell and colour shades (Palmer & Hoffman, 2001), most research vouches for the effectiveness of this technique for landscape assessment (Shafer & Brush, 1977; Stewart *et al*., 1984; Hull & Stewart, 1992). Furthermore, infographic simulation starting from a photographed scene makes it possible to compare and evaluate different possible scenes (Bishop & Leahy, 1989; Tress & Tress, 2003; Dockerty *et al*., 2006; García *et al*., 2006; Ghadirian & Bishop 2008; Pinto-Correia *et al*., 2011; Barroso *et al*., 2012)

All the photographs used in the study, both in Sweden and in Spain, were taken by camera and every scenic composition was shot from transportation routes following the methodology of Montero *et al*., (2008a). Moreover, care was taken that the building should have a scenic occupation of 30 % to 50% of the photographed scene, making it possible to compare the building scenes with their most immediate setting (Figure 11).

Figure 11. Typical building in the region of Norrland, northern Sweden

Following the criteria laid down above, eight scenarios were selected (four scenarios from Spain and another four from Sweden) from all the photos of the cases sampled in Sweden and Spain. And from each case, the most representative photo was chosen. By means of infographic simulation three possible hypotheses were obtained from each of the eight study object scenarios. This gave 24 scenarios altogether modifying the vegetation existing behind the building (Figure 11). This process was always performed with Adobe Photoshop CS5 ® software, without altering in any case the building in the original picture. The infographs were modified by varying the height of the vegetation behind the building. The diverse vegetation versus building height ranges were laid out according to the Weber-Fechner Law (Nasar & Stamps, 2009). Once the infographs created were submitted to a panel of experts, it was determined that the answers of the respondents were sensitive by a ratio of ½ compared to the height of the building. Thus the following height ratios were laid down:

1. The vegetation does not exceed the height of the building's eaves (Figure 12)
2. The vegetation exceeds by 0% to 50% the building's height (Figure 12)
3. The vegetation exceeds 100% of the building's height (Figure 12)

Figure 12. Mosaic of the 24 infographs submitted to survey in both countries

2.2.4. METHODOLOGY OF THE SURVEY (1)

In order to test the responses to the diverse scenario, a study was carried out on paper format. A printed version of the survey of the 24 scenarios under study was given to the respondents in a face-to-face situation. A representative of the research group was present during the duration of the survey (Lange *et al.*, 2008). The infographs were shown at random to each person so as not to influence the responses in the survey. (Arriaza *et al.*, 2004; Paar, 2006; Lange *et al.*, 2008; Christopher *et al.*, 2011; Pinto-Correia *et al.*, 2011).

2.2.4.1. LAYOUT OF THE QUESTIONNAIRE

The paper questionnaire has two sections. The introductory section consists of a letter of introduction to the survey and an additional page asking the respondents for personal details. This includes questions on sex, age, home address and educational background (Figure 13).

Respondent data						
Age:	☐ ≤ 25	☐ 26 – 64	☐ ≤ 65	Gender:	☐ M	☐ F
City:			Country:			
Level of education:						

Figure 13. Personal details of the respondents

In the main section of the survey, the respondents were requested to indicate their scores on the integration of the buildings in the landscape ('How would you rate the integration of the building in the scene photographed?'), by assessment of a series of 24 colour pictures. All the pictures were laid out horizontally and were shown on individual A4 sheets which allow for the reproduction of the infographs in high quality.

Under each picture the respondents were provided with a rating scale of five options “Very bad, Bad, Acceptable, Good and Very Good” (García *et al.*, 2010). Although rating scales with more intervals can be used (for example Roth, in 2006, who uses a 10 point scale), Lange *et al.*, (2008) points out that many grades within a rating scale may end up confusing the respondents when rating the scenarios. By using a five-option scale, each option on the scale corresponds to a verbal description, which suggests a underlying cuasi-metric scale (Lange *et al*., 2008).

The surveys were carried out in Spanish and in English. Thus we ensured national and international participation in the integration of buildings in the landscape in both countries.

2.2.4.2. CHARACTERISTICS OF THE RESPONDENTS (1)

Results were obtained from 75 respondents during the survey phase. 42 were interviewed by students of Extremadura University and the rest by students of Gävle University, in Sweden.

Altogether 42 surveys were carried out in Spain. The majority of respondents (31) are aged ≤ 25, of whom 25 are men and 17 women. Moreover, all the respondents are university students. Altogether 33 surveys were carried out in Sweden. As in Spain, all respondents are university student aged ≤ 25, of whom 18 are men, while 15 are women.

Since the sample has not been representative of all ages and professions, no analysis has been applied to detect any possible population effects on these variables. The shortage of data in categories superior to those sampled prevents a more extensive analysis.

2.3. EXPERIMENT III: THE APPLICATION OF SCREENS OF NATIVE VEGETATION TO LESSEN IMPACT ON THE LANDSCAPE: METHODOLOGY AND CASE STUDIES

The main objective of this work is to detect how the variation in distinct percentages of the building covered by screens of vegetation can affect the visual perception and evaluation rating of the same in its immediate surroundings.

In order to achieve this objective, digital image analysis techniques are used along with scenario simulation starting from real photos. Several practical cases picked from northwestern Spain are used to these ends. Distinct filtering percentages with distinct vegetation types are simulated over these initial buildings. The results show how the species of vegetation and the amount of screening or filtering affect the visual interpretation of the constructed volume.

2.3.1. DESCRIPTION OF THE STUDY AREA

This work was carried out in the Biosphere reserve of Sierras de Béjar y Francia, in the south-east of Salamanca Province, in the north-west of Spain. Though there are euro-siberian influences, the Reserve is part of the Mediterranean region, and affects 88 municipalities altogether, over an area of 199,140 hectares. This area has been zoned as shown in table 2.

Table 2. Zoning of the Biosphere Reserve of Sierras de Béjar y Francia

Zoning	ha	%
Core Zone	24,385	12.24
Buffer Zone	113,197	56.84
Transition Zone	61,558	30.91

The *core zone* covers the most significant areas of the Reserve and is not greatly used by man nor is it home to activities of great environmental impact. There are no population nuclei within it. The *buffer zone* surrounds the *core zone* and is not home to any population nuclei either, although it is permanently used by man, since this is where the main economic activities are carried out, namely agriculture and stock farming. This zone is also home to most of the forestry land and hunting grounds. The *transition zone* is where most of the anthropogenic action is concentrated, and it is of vital importance to attain sustainable management of the territory because it is where the traditional crops are to be found around the villages, where the references to traditional architecture are preserved and where most of the tourism concentrates.

The area is mountainous with abrupt relief altitudes ranging from 360 to 2,425 metros. As well as the mountain ranges (Sierra de Béjar y Sierra de Francia), there are pronounced valleys such as those of the rivers Alagón, Tormes, Francia, Quilamas, Sangusín and Cuerpo de Hombre. The differences in altitude, the extensive hydrographic network and the varied climatic conditions mean there is a wide variety of ecosystems, ranging from high mountain to riverside woodlands, including rocky areas and granite outcrops, peat bogs and woodland of tree species, notably holm oaks, pyrenean oak, portuguese oak, sweet chestnut, strawberry tree, dehesa systems, ash and pine. Linked to the ecosystems and the species of flora is to be found a wide range of fauna. Noteworthy examples include, among others, the iberian lynx, black stork, griffon and black vulture, golden and bonelli's eagle, otter and various game species.

The district is of predominantly stock-farming character, with traditional extensive stock-farming practices, though arable farming has also played an important part in the human history and in landscape formation, with traditional hillside terracing common in the area. Local relief and climate have determined the traditional architecture, giving rise to a sturdy building style which is both practical and beautiful.

A series of threats have been detected in all the municipalities of the Reserve, which, if not taken into consideration and acted on correctly, could have an adverse environmental and socio-economic effect on the region. Foremost among them are the neglect of residential nuclei, the architectonic heterogeneity, incomplete or unfinished town planning for the transition area; the loss of land use or inappropriate use in the *buffer zone*; and large infrastructures and changes in dominance in the *core zone*.

In order to select the municipalities to be studied, several trips were taken to the area to identify which ones had most buildings out of place with the surroundings or which were very representative. In a previous meeting with the Asociación Salmantina de Agricultura de Montaña (ASAM) (Salamanca Association for Mountain agriculture), the municipalities were screened and the Association gave advice all through the selection process. All the field trips followed the same procedure: locating and photographing the buildings which clashed with their urban or natural setting. The cases evaluated in this work were existing residential buildings in the urban nuclei, leaving for later studies farm or industrial warehouses as well as other building typologies out of the built-up area photographic analysis led to the selection of the eight priority municipalities shown in figure 14: Cepeda (population 400), Horcajo de Montemayor (population 170), La Calzada de Bejar (population 101), Lagunilla (population 549), Navacarros (population 132), Sotoserrano (population 655), Valdefuentes de Sangusín (population 257) and Valero (population 361).

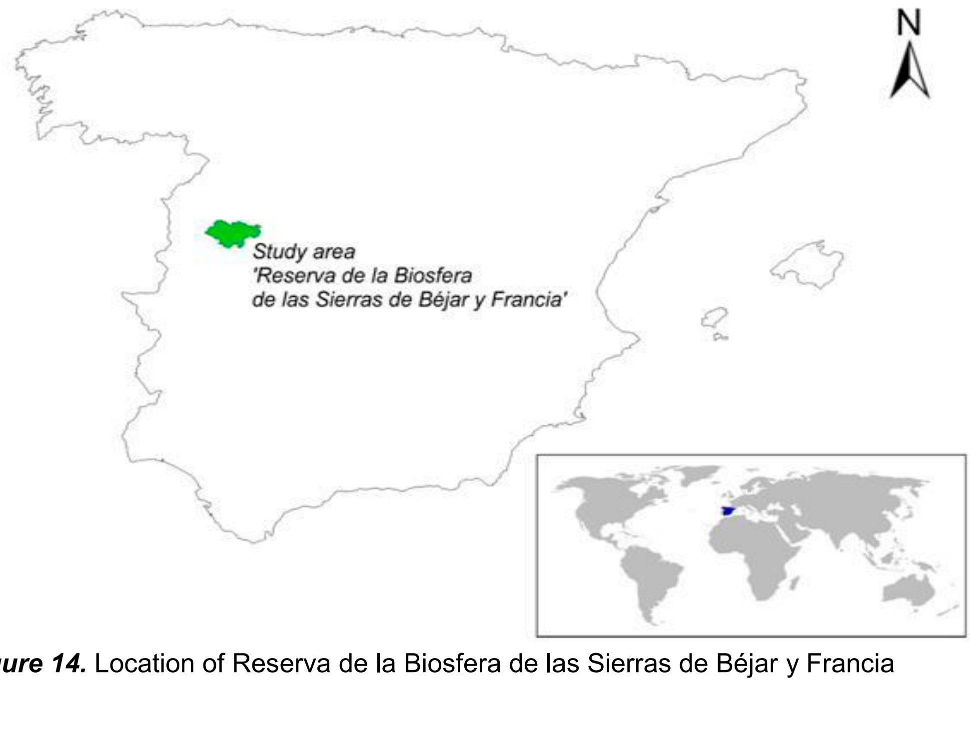


Figure 14. Location of Reserva de la Biosfera de las Sierras de Béjar y Francia

2.3.2. INFORMATION GATHERING

The first step in the work was to visit each and every one of the eight population nuclei selected by the ASAM, in order to locate and record possible case studies. The criteria that the buildings had to meet so as to be considered case studies were as follows:

- Not be built in the style of local traditional architecture.
- Be in a state of severe neglect.
- Be of a colour or texture which is out of place in the area.
- The building is higher than the rest of the dominant elements

This first visit led to ruling out two of the villages previously selected: La Calzada de Béjar and Navacarros, as they had no obvious case studies. The six remaining villages (Lagunilla, Valero, Valdefuentes de Sangusín, Horcajo de Montemayor, Cepeda and Sotoserrano) gave a total of thirty case studies. The five cases analyzed in Horcajo de Montemayor are shown below as an example (Figure 15). For each of the cases selected, a scoreboard has been drawn up which gathered the following data (Table 3).

Table 3. Scoreboard drawn up for data capture in each case study

Village	
Case nº	
Coordenates	**X**
	Y
Altitude	
Photos	**Nº Inicial**
	Nº Final
Building	**Height**
	Width
Vegetation	
Comments	

The coordinates of the building and its altitude are established by means of GPS Garmin Colorado 300; the photographs of all the study were taken on a Canon 350D camera while a VERTEX Laser Hypsometer was used to discover the height of the building.

Figure 15. Location and cases studied in Horcajo de Montemayor (Salamanca)

2.3.3. PHOTO CAPTURE (2)

Although some authors question the validity of the photographic method and express their doubts about whether a photo can represent a complex scene and whether it is impossible to evaluate in the office attributes which are not perceptible via photos, such as sounds, smells and shades of colour (Kroh & Gimblett, 1992; Palmer & Hoffman, 2001), most studies vouch for the usefulness of this technique in landscape assessment(Dunn, 1976; Shafer & Brush, 1977; Shuttleworth, 1980; Stewart *et al.,* 1984; Hull & Stewart, 1992; Wherrett, 2000; Pérez, 2002). Moreover, info-graphic simulation originating in a photographed scene makes it possible to compare and evaluate distinct possible scenes (Bishop & Leahy, 1989; Tress & Tress, 2003; García *et al*., 2006; Dockerty *et al.,* 2006; Ghadirian & Bishop, 2008)

The photos were taken at the distances and from the angles that captured as many details as possible of the buildings selected. In this sense, the distances considered suitable are those which allow for 30-50% scene occupation by the building (Montero *et al.*, 2008a). Moreover, frontal viewpoints, as opposed to others with perspective, do not appear to have a detrimental effect on the visual analysis of a façade (Stamps III, 1993), for this reason they have been used indistinctively in the study photos of façades. At the end of the day, the photos were taken exclusively according to determining factors of accessibility and visibility of the building. Lastly the photos were taken from well-used roads or streets, keeping the direct line of observation as perpendicular as possible to the façades under study (Herzog & Shier, 2000). (Figure 16).

From the total of thirty cases found, eight were selected at random following the criteria laid down above. And from each case the most representative photo was picked (Table 4). To be considered as such, the photo must be taken from very busy routes of communication, while showing the main façade visible from this point. Then, three possible assumptions are obtained from each of the eight scenarios which are object of study, by means of info-graphic simulation, by modifying the quantity of vegetation existing in front of the building. In four of the eight cases picked, climbing plants were used (Table 4) and tree species in the remaining four cases (Table 4). All species were native to the area.

Figure 16. Photo taken according to the methodology laid down for the study, in the village of Valero.

Table 4. Final cases selected for the study. The superscript indicates the type of plant used: tree (1) or climber (2)

Village	Id_case	Coordinates		Height of building (m.)	Vegetation
Cepeda	CEP07	29T0751255	4484252	11,8	*Quercus pyrenaica*[1]
Horcajo de Montemayor	HOR05	30T254697	4479007	8,5	*Quercus pyrenaica*[1]
Lagunilla	LAG05	29T248318	4468147	8.7	*Hedera* helix[2]
Lagunilla	LAG09	29T248111	4468336	7	*Castanea sativa*[1]
Sotoserrano	SOT02	29T0751896	4480517	10	*Hedera hélix* And *Buxus sempervirens*[2]
Valero	VAL02	30T0250674	4491342	8.7	*Hedera helix*[2]
Valero	VA05	30T0250802	4491561	8.9	*Vitis vinifera*[2]
Valdefuentes de Sangusín	VDS01	30T259958	4483514	9.5	*Quercus pyrenaica*[1]

To obtain these 24 scenarios, three info-graphs were taken from each of the case studies by modification of the quantity of vegetation existing in the building foreground. This process was carried out using Adobe Photoshop CS5 ® software, and never altered the construction of the original shot. The info-graphs were modified by altering the percentage of filtering produced by the vegetation on the building, as such a way that:

1. There is no vegetation on the info-graph, which gives 0% filtering. (Figure 17).
2. The vegetation gives filtering of up to 50%; in no case have percentages under 40% been used (Figure 18).
3. The vegetation produces a maximum filtering of around 80%; in no case have percentages under 70% been used (Figure 19).

Figure 17. Real scenario, without vegetation. Initial building VAL02 (Table 4).

Figure 18. Simulated scenario, in which the vegetation gives a filtering of up to 50%. Modified building VAL02 50 (Table 4).

Figure 19. Scenario created with Adobe Photoshop CS5 ® software, in which the vegetation produces filtering at a maximum of 80%. Modified building VAL02 80 (Table 4).

To count the percentage of filtering achieved by the vegetation, the Adobe Photoshop CS5 ® software was used. Figure 20 shows how the histogram displays the pixels contained by the object selected, in this case, the building shown.

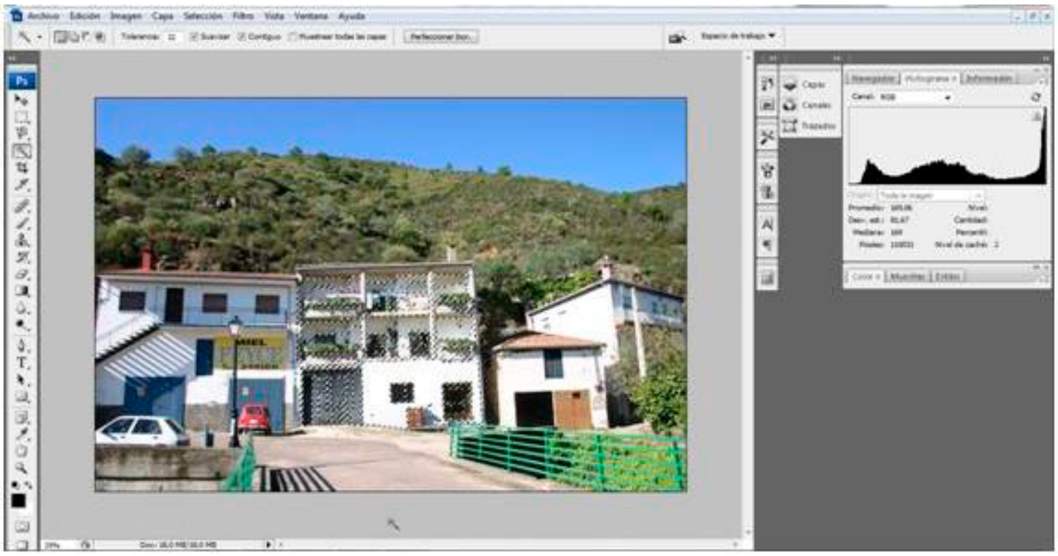


Figure 20. Procedure to calculate filtering of vegetation with Adobe Photoshop CS5 ®.

The percentage of filtering of each building has been calculated by dividing the number of pixels occupied by the vegetation in the façade by the total number of pixels of the same. Thus the filtering that existed in each info-graph was calculated (Table 5).

Table 5. Summary of the filtering obtained in each one of the 16 info-graphs generated from the 8 real ones. The numeration established for each case is formed by the identifier of each real case (Table 4), followed by 50 or 80, according to the filtering applied in this info-graph.

Village	Case	px. Casa	px. Vegetation	%
Valero	VAL02 50	214182	111509	52,06
Valero	VAL02 80	214182	168162	78,51
Lagunilla	LAG09 50	243826	125496	51,47
Lagunilla	LaG09 80	243826	191219	78,42
Horcajo	HOR05 50	48683	22162	45,52
Horcajo	HOR05 80	48683	35994	73,94
Valdefuentes	VDS01 50	79467	35736	44,97
Valdefuentes	VDS01 80	79467	59370	74,71
Valero	VAL05 50	135648	76424	56,34
Valero	VAL05 80	135648	101015	74,47
Sotoserrano	SOT02 50	105378	48868	46,37
Sotoserrano	SOT02 80	105378	76020	72,14
Lagunilla	LAG05 50	39866	19438	48,76
Lagunilla	LAG05 80	39866	31930	80,09
Cepeda	CEP05 50	65953	28522	43,25
Cepeda	CEP05 80	65953	54426	82,52

2.3.4. ELABORATION OF THE SURVEY (2)

Works previously found in the literature speak of possible emotional links to everyday or familiar scenarios, as opposed to others that are not so well-known (Coeterier, 2002), as well as the possible influence of academic background or level in the appreciation of a landscape (Kongjian, 1995). To compare possible results along these lines, two groups of respondents are considered in this work: local people without a university education, and non-locals with a university education. So, on one hand, students of Extremadura University with no links to the study municipalities, and on the other, inhabitants of La Calzada de Béjar without any university education were interviewed.

The 24 info-graphs were shown randomly, so that the results would not be affected by the presentation order of the images (Imamoglu, 2000). On seeing each info-graph, the respondents had to evaluate the integration of the building in terms of visual preference, via an ordinal ascending scale with five options from “Very Bad”= 1 to “Very Good”= 5. Ascending value scales, like the one here, are a simple and efficient measure of the hedonic tone of the respondent facing a visual stimulus, as is shown by other research (Nasar, 1983), and therefore is considered ample for the work objectives.

2.4. EXPERIMENT IV: VISUALIZATION OF VIDEOS AND 3D SCENARIOS TO ASSESS VARIOUS VEGETATION SCREENS FOR INTEGRATION OF BUILDINGS IN THE LANDSCAPE

The main objective of this study is to research the integration of buildings in the landscape by visualizing the scenarios in three dimensions (3D) with videos and study techniques which encourage a greater public participation. As well as modeling in 3D the “status quo” of the two study zones, vegetation screens are to be placed around a type building, altering their density, species and layout. Once the scenarios have been established, videos at different speeds will be generated to simulate touristic activities that can be carried out in the open air. The 3D models generated will be submitted to surveys in order to facilitate public participation and to assess the respondents’ preferences concerning the various videos generated. For the execution of this study, two experimental research zones were chosen: one representing rural settings in the district of the Ambroz valley, Cáceres (Spain) along with a second zone in the south of Huelva (Spain), corresponding to coastal settings.

2.4.1. STUDY AREAS: PLOT SELECTION

For the execution of this study, two experimental research zones were chosen: one representing rural settings in the district of the Ambroz valley, in the north of Extremadura (Spain), and a second zone in the south of Huelva (Spain), corresponding to coastal settings. (Figure 21).

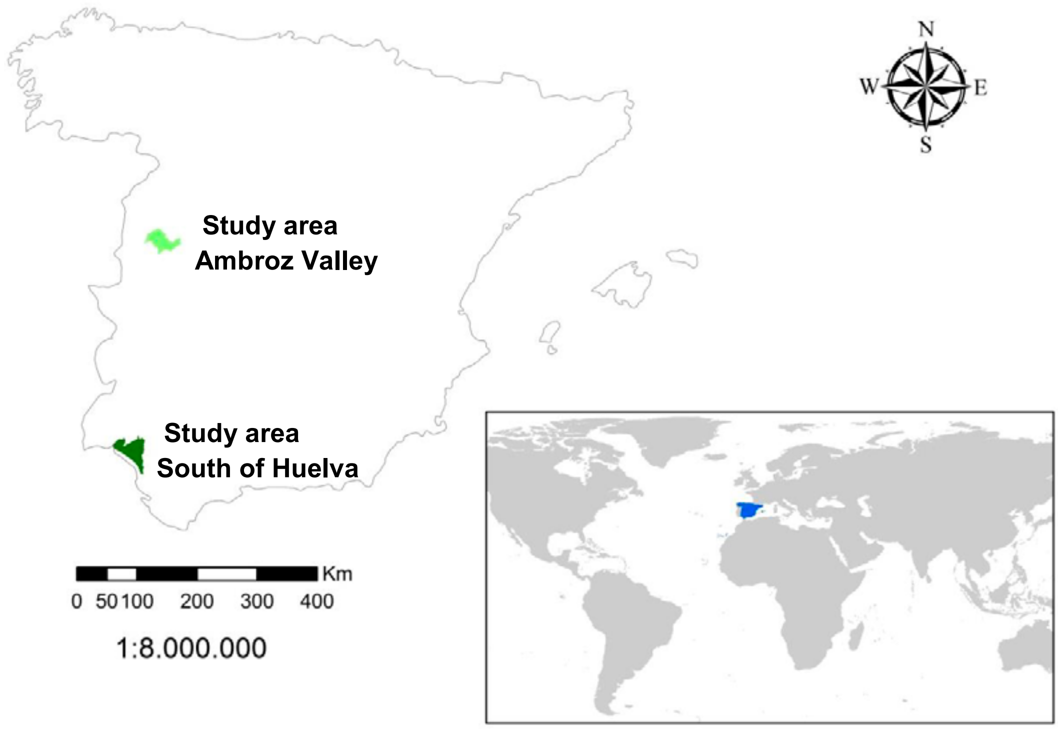


Figure 21. Location of the study areas representing rural settings in the Ambroz valley, and coastal settings in the south of Huelva

2.4.1.1. AMBROZ VALLEY STUDY AREA

The experimental zone under study in rural settings corresponds to the municipality of Hervás. This is in the Ambroz Valley district, in the north of Cáceres Province (Spain) and in the foothills of the Gredos and Béjar mountains.

In terms of physical environment, the Ambroz valley has natural diversity of great quality due to its range of altitude: from 400 to 2102 m. Thus it provides the optimal growing conditions for sustainable, mature woodland.

The woodland systems to be found in the Ambroz valley are:

- High mountain woodland, which on account of the climatic conditions is home to heather, cytisus spp, brooms, high mountain grazing land, moss, lichen etc.
- Atlantic woodland, deciduous and rich in vegetation, including sweet chestnut, oak, holly, yew, etc,

- Mediterranean woodland, consisting of holm oak and old cork oak woods, cultivated areas and irrigated flat valley bottoms. It is to be found at lower altitudes.

After characterizing the vegetation in the study area, the next step was to perform a field visit to various buildings and woodland masses in order to check the features, both natural and in building terms, of the Ambroz valley, in order to select buildings in the natural environment for the development of the methodology of this research project.

In order to standardize the method, a search was made of structures of combined experimental vegetation and building, which were to be found in general in the entire Ambroz valley.

Each building and vegetation element within the plot was measured as required using the VERTEX Laser Hypsometer (height of building, height of adjoining vegetation) as well as its UTM coordinates for subsequent treatment in Geographic Information System.

2.4.1.2. SOUTH HUELVA STUDY AREA

Part of the Cartaya municipality was chosen as coastal experimental area, since it is fairly representative of town-planning activities linked to woodland in coastal areas.

The municipality of Cartaya has 17,424 inhabitants and an area of 226 km^2, with an average height above sea level of 26 m. Although the main urban nucleus is 9 km from the coastline, there are two urban developments by the sea: El Rompido and El Portil, 7 km from each other. Between these three nuclei are to be found the Pinewoods of Cartaya, 12.000 ha altogether of pines (*Pinus pinea*) and juniper (*Jumperus communis).* Following the criteria laid down for the selection of vegetation and building type under study in the Ambroz valley, the next step was to search for structures of combined experimental vegetation and building, which were found in general in the Cartaya Pinewoods.

2.4.2. ANALYSIS OF THE INFORMATION GATHERED

2.4.2.1. GENERATION OF 3D SCENARIOS

The aim of the generation of 3D scenarios is to provide the foundations from which a person can analyze, interpret and react to the visual experience of the landscape (Lange *et al.*, 2008). We chose SketchUp 8 Pro © as modeling software and ArcGis 10 © as the platform to visualize and establish the scenarios (Chang *et al*., 2009; Li *et al*., 2011).

The landscapes were represented in various resolutions in order to provide an ideal resolution, at the same time as the digital model makes it possible to be computationally efficient (Lange *et al*., 2008). A digital model of terrain elevations with a resolution of 25 metres and an orthophoto with a 2.5 m resolution was established for the scenarios of north Extremadura and south Huelva. The real virtual model of the sites under study consisted of an orthophoto with a 1 m resolution. The 3D objects such as buildings and trees were placed in the ArcScene module of ArcGis 10 © in the MDT (digital terrain model) which was built as a TIN (triangular irregular network). In order to obtain an accurate terrain representation, some embankments, tracks and paths were edited by hand. The modelling and texturization of the 3D elements was based on data gathered in the field in the two study areas, as was explained in the previous section (Figure 22).

In order to obtain an accurate representation of the existing vegetation, the trees within the study plots were photographed. A library of textures was drawn up, based on these photos, of local woody plants such as *Quercus pyrenaica, Pinus pinea* and *Castanea sativa*. Once the models had been produced as described, the small alterations in composition could be carried out with comparative ease (Figure 23).

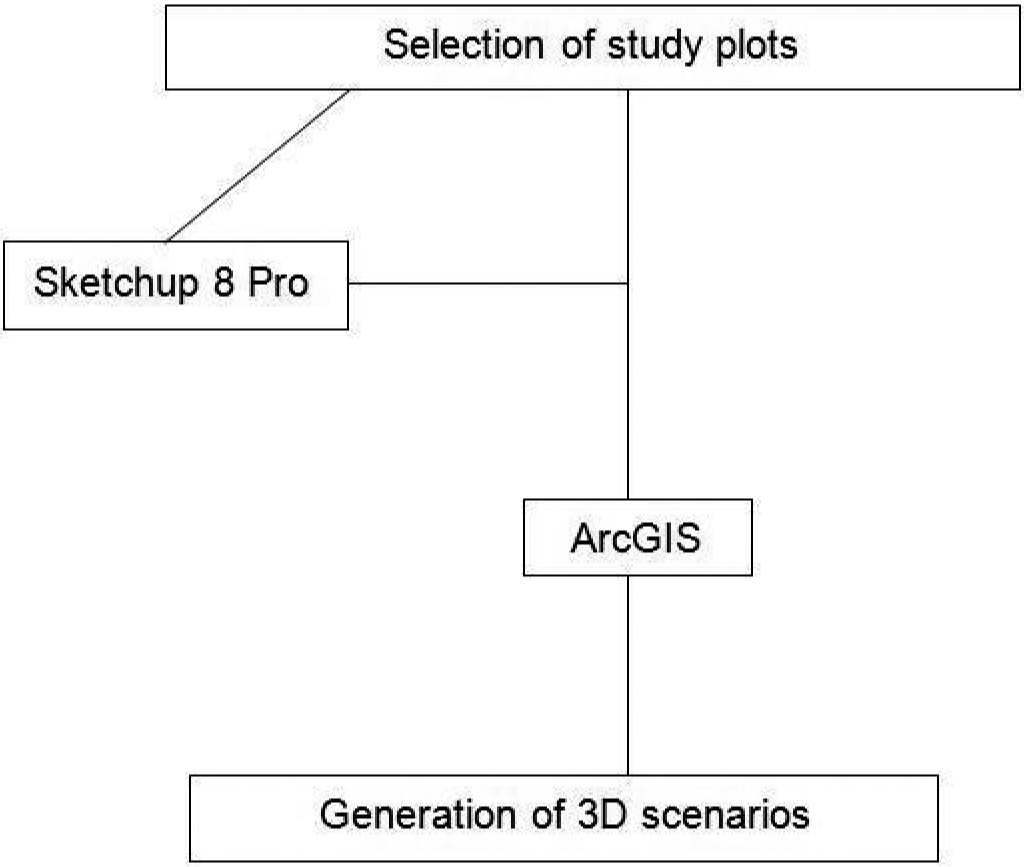


Figure 22. Process of generation of 3D scenarios

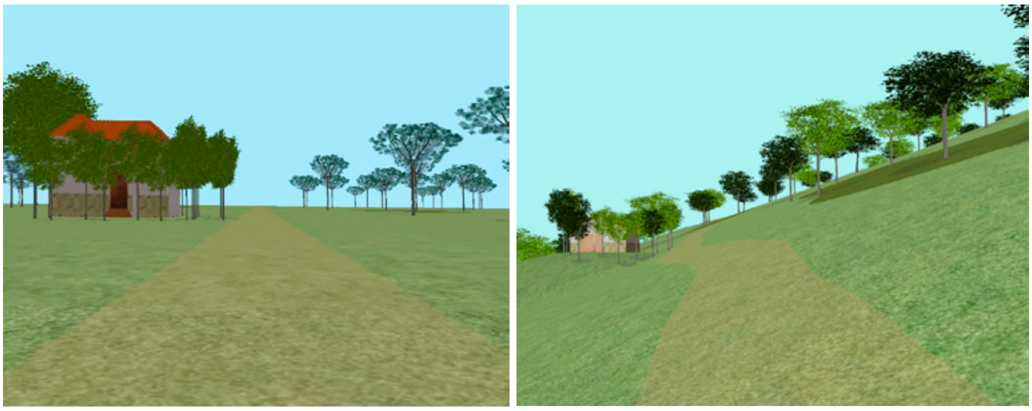


Figure 23. On the left, the scenario modeled in 3D of South Huelva and a representation of a Pinewood. On the right, the scenario modeled in 3D of North Extremadura with the representation of mixed Woodland with oak and chestnut.

2.4.2.2. VIDEO VARIATIONS AND GENERATION

Steinitz *et al*., (2005), define a scenario as “a scheme or diagram for a future landscape””. Ringland (1998), emphasizes the importance of communicating the contents of the scenario: “The scenarios are the ideas, and ideas are very hard to communicate”.

Over the last decade there has been an increase in the representation of visual scenarios. Some works include digital photomontage (Montero, 2008a; Barroso *et al*., 2012), and generation of different scenarios and video in 3D (Pullar & Tidey, 2001; Ghadirian & Bishop, 2008; Zhang & Huang, 2012). Currently there is an ever increasing use of 3D generation of scenarios and videos for landscape visualization and environmental planning. (Paar, 2006; Lange *et al*., 2008; Hayek, 2011).

In our study two virtual scenarios were modeled, characterizing them with native vegetation and a building which is typical of the areas. The following variations were introduced in both scenarios:

1. For the north of Extremadura, mixed Woodland of oak and sweet chestnut was designed as the most representative species of the plots under study. A typical building of the surrounding area was also modeled in this scenario, and around it were placed vegetation screens of varying density (low and high), species (pine, chestnut, and mixed composition: oak and chestnut) and layout (linear and irregular). Once the scenarios have been established, videos will be generated at different speeds to simulate touristic activities that can be carried out in the open air. (Table 6).

This gives a total of 9 videos for each scenario, as can be appreciated in figure 24. Each capital letter represents a video (A, B, C) at a determined speed and tree density around the building, without repeating the same capital letter in the same row and in the same column (Nasar & Stamps, 2009). This matrix pattern, called “Latin square” (Figure 24) makes it possible to compare and obtain results with statistical solidity regarding which compositions, species and types of activity (speed) are the most highly rated for the integration of each building in the surroundings; and all this at a minimum cost in terms of the number of simulations.

Table 6. Each capital letter represents an open air activity performed at a certain speed and duration.

Capital letter	Open air activity	Speed and Duration
A	Simulating a person walking	60 seconds
B	Simulating a person cycling or horse-riding…	40 seconds
C	Simulating a person on quad, motorbike, car	20 seconds

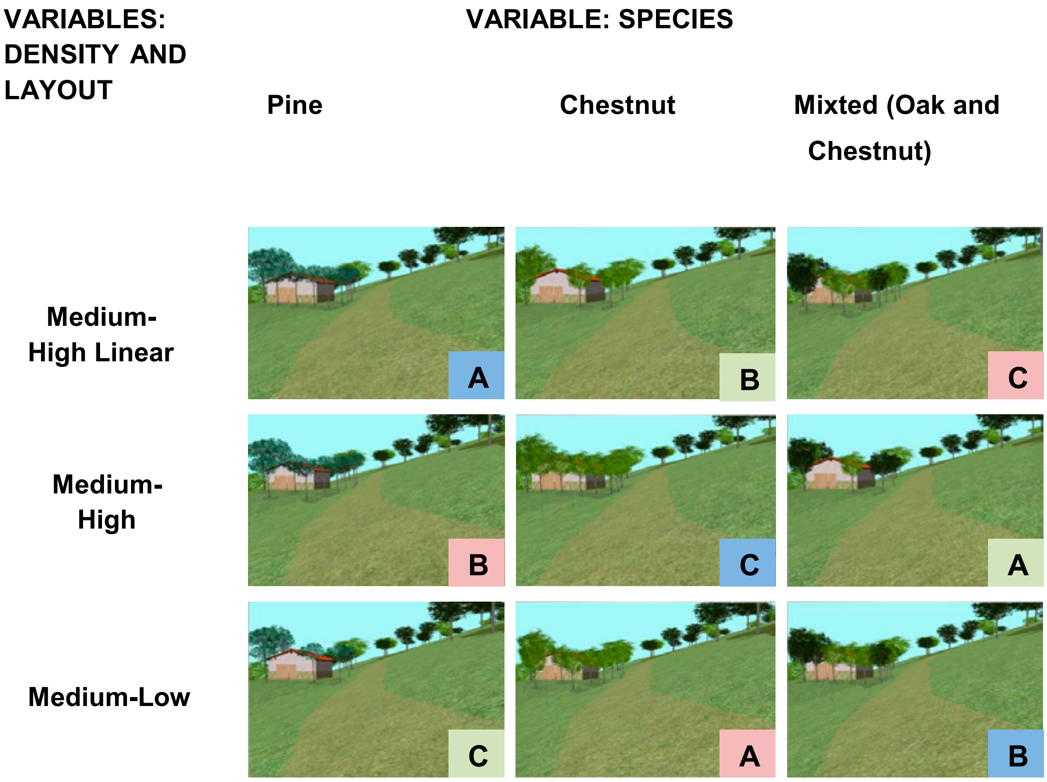


Figure 24. Mosaic of images in which we can appreciate the different layout and density of vegetation around the building in the modeled scenario for the north of Extremadura. Each capital letter represents a video with a determined speed and duration.

2. For the south Huelva scenario, a Pinewood was designed as the most representative species in the plots under study. In this scenario, a building typical of its surroundings was also modeled, around which were placed vegetation screens of varying density, species and layout, in order to compare and find which layout and species in the most suitable for the integration of the building in its surroundings. In order to standardize the method, the video generation process described for the north Extremadura scenario is repeated.

2.4.3. METHODOLOGY OF THE SURVEY (3)

A pilot study was previously performed which revealed that 9 videos per person was too many in terms of the respondents' tiredness (Wherrett, 2000; Lange *et al.*, 2008). Therefore the total number of surveys per study area (north Extremadura and south Huelva) was kept to three. So as to complete the matrix design in each survey, three videos have been presented according to the color of the cells, as can be seen in table 7. This makes it possible to compartmentalize the design, maximizing the variability of the cases presented according to the variables under study, minimizing the respondents' visual effort.

Table 7. Design of Latin square for case analysis. The different colours mean different surveys. Each respondent has only seen the cases of the same colour

Tree Density	**Pine**	**Chestnut**	**Mixed (Oak and Chestnut)**
Medium-high linear	A	B	C
Medium-high irregular	B	C	A
Medium-low	C	A	B

The nine videos elaborated according to the matrix design proposed were submitted to a survey divided into two sections, and a web platform was designed for it. An introductory section consisted of a letter of presentation for the survey and an additional page asking the respondents for personal details. This included questions on gender, age, place of residence, educational background and professional status.

In the main section of the survey, respondents were asked to give their assessment of touristic activities in the open air in three of the proposed itineraries according to a sequence of random videos assigned (Table 7). To these ends, the respondent had to answer the following question on seeing each video: how would you assess this itinerary for doing open-air touristic activities? So as not to influence the response, the videos were shown in random order for each person. (Arriaza *et al*., 2004; Paar, 2006; Lange *et al*., 2008; Christopher *et al*., 2011; Pinto-Correia *et al*., 2011). All the videos were displayed horizontally and were shown on separate pages which made it possible to see them full screen. Under each video there was a rating scale of five options for the respondent: “Very Bad, Bad, Acceptable, Good and Very Good” (García *et al*., 2010). Although rating scales with smaller intervals can be used (e.g., Roth, 2006, who uses a 10 point scale), Lange *et al*., (2008) point out that many levels within a rating scale can confuse the respondents when they come to rate the scenarios. On a five-option rating scale, each option corresponds to a verbal description, which implies a subjacent quasi-metric scale (Lange *et al*., 2008).

To conclude the study there is an open-type final question to debug the results and establish possible future lines: Would you change anything in the videos you have just seen? (If so, give brief reasons).

The surveys were conducted in Spanish, as the respondents chosen for the study were Spanish.

2.4.3.1. CHARACTERISTICS OF THE RESPONDENTS (3)

In the survey stage, results were obtained from 85 respondents, who did one of the three surveys drawn up for south Huelva study area. Most of the respondents (72) ranged from 25 to 55 years of age, 46 men to 39 women. Most (45) reside in urban areas of 10000-500000 inhabitants. Lastly, a university education is the professional status which stands out most in the sample of participants (58).

Results were obtained from 84 respondents in the north Extremadura study area. Most (62), ranged from 25 to 55 years of age, 42 men to 42 women. As was the case in south Huelva, most of the respondents (41) came from urban areas of 10000-500000 inhabitants. Lastly, a university education is also the professional status which stands out most in the sample of participants (44).

Seeing that the simple was not representative of all ages and professions, no analysis was applied to detect any possible population effects on these variables. The shortage of data in categories superior to those sampled prevents a more extensive analysis. Future works could incorporate greater diversity of respondents.

3. RESULTS AND DISCUSSION

3.1. ESTIMATION OF OPTICAL POROSITY OR CANOPY STRUCTURE OF TWO SPECIES OF TREE WITH HEMISPHERICAL AND VERTICAL IMAGES

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).

3.1.1. *CASTANEA SATIVA*

Table 8 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 modeling the filtering or obstruction versus tree growth, it is important to analyze the advantages of vertical as opposed to hemispherical photography. Using linear regression analysis (Figure 25) 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 8. 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

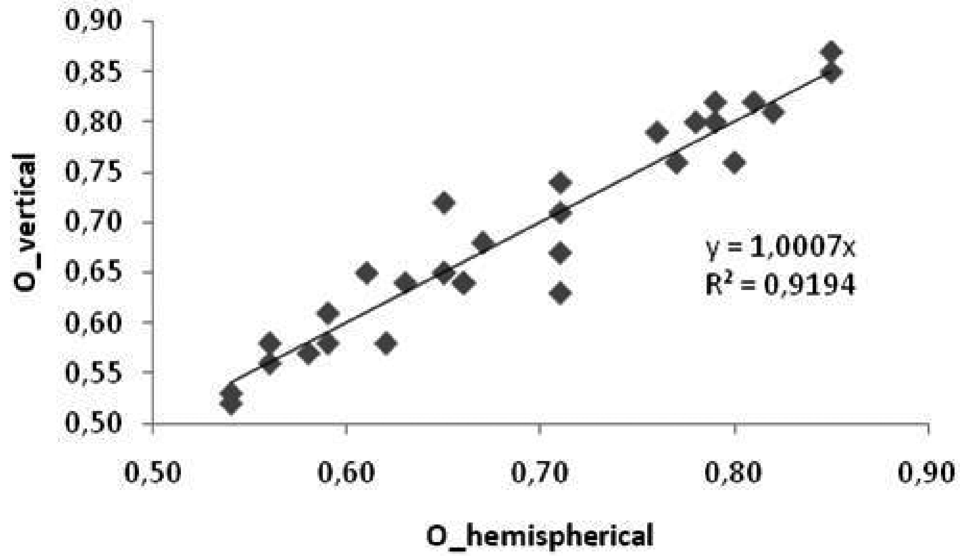


Figure 25. Comparison of the degree of obstruction obtained for chestnut with both photographic methods

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 model the plant structure.

In this sense, DBH is the variable which most biological importance has had in other works consulted (Montero *et al.*, 2008b), 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.*, 2008b), (Figure 26).

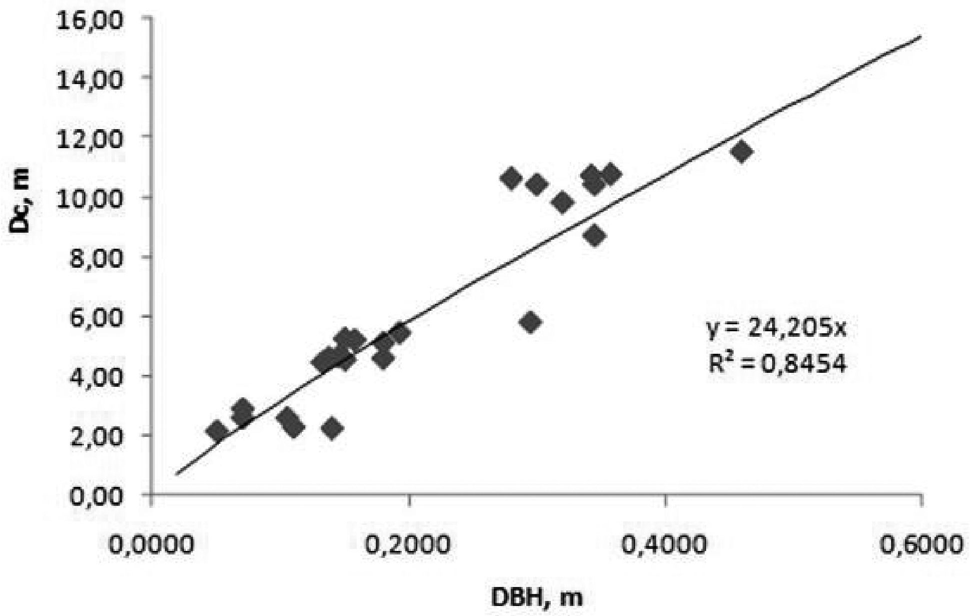


Figure 26. Exponential trend of the allometric variables of significance in the growth of tree canopy of chestnut

Both aspects are therefore the selected parameters from the perspective of obstruction coefficient (or its filtering 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 figure 27 it is possible to appreciate the filtering 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 model the amount of filtering that a typical chestnut (under the conditions set for this study) can develop throughout its growth.

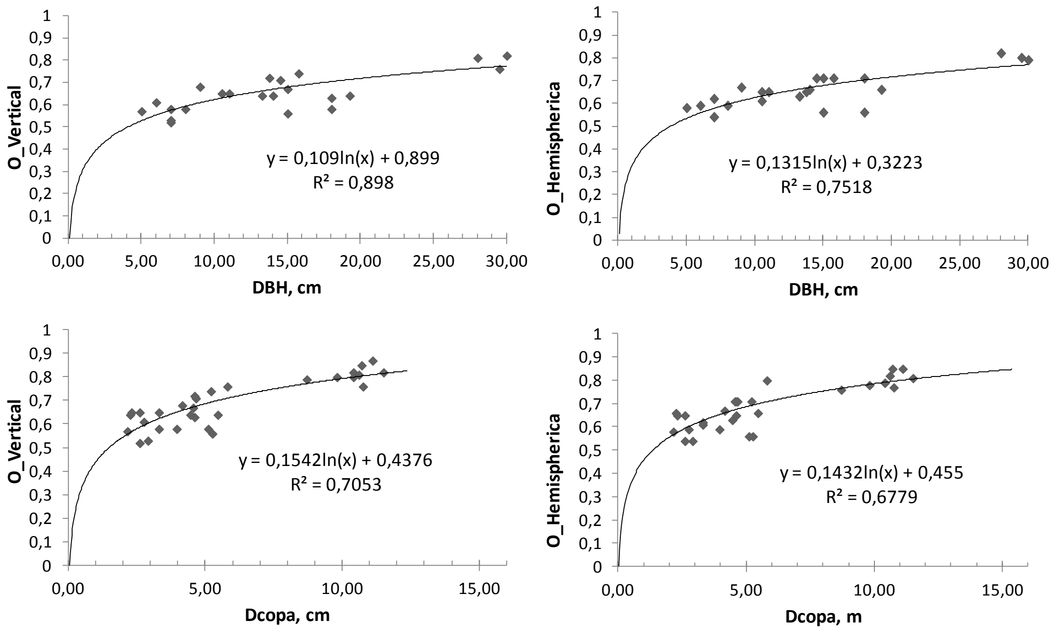


Figure 27. Logarithmic relationship of the models to estimate the filtering capacity of chestnut, starting from DBH and Dc, for both types of photographic acquisition.

3.1.2. *QUERCUS PYRENAICA*

Using the same protocol set out for the chestnut, in table 9 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%) (Figure 28) 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.

Table 9. 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	3,1	3,7	3,4	11,5	0,64	0,63
2	A	13	2,3	4	3,15	11	0,62	0,66
3	A	16,75	3,4	3	3,2	9,5	0,62	0,66
4	A	15	2,8	2,3	2,55	8,3	0,56	0,62
5	A	17,5	3,3	3,5	3,4	9,7	0,6	0,63
6	A	14	3,6	3,7	3,65	8,3	0,61	0,63
7	A	14,25	4,3	4	4,15	9,8	0,64	0,6
8	A	13,25	2,8	3,9	3,35	9,6	0,64	0,62
9	A	15	4	2,7	3,35	10,9	0,68	0,66
10	A	16,5	3,8	4	3,9	12,7	0,68	0,67
1	B	35,25	9,6	9,6	9,6	9,4	0,86	0,88
2	B	45,5	11	11	11	9,8	0,89	0,86
3	B	27,25	5,5	5,5	5,5	7,6	0,88	0,85
4	B	39	11,5	11,5	11,5	7,6	0,9	0,87
5	B	43,7	12,5	12,5	12,5	11,2	0,9	0,86
6	B	40	10,5	10,5	10,5	9,6	0,91	0,87
7	B	39	11,5	11,5	11,5	10,3	0,9	0,87
8	B	39,78	10,35	10,35	10,35	8	0,89	0,85
9	B	33,42	9	9	9	7,7	0,9	0,9
10	B	46,15	10,7	10,7	10,7	10,8	0,9	0,88
1	C	6	1,5	1,8	1,65	6,2	0,55	0,51
2	C	5	1,4	1,3	1,35	4,2	0,49	0,49
3	C	8	1,8	1,7	1,75	6,4	0,5	0,54
4	C	10	1,3	1,3	1,3	8	0,57	0,54
5	C	11	3,1	2,1	2,6	7	0,63	0,56
6	C	8,5	2	1,9	1,95	5	0,57	0,55
7	C	7,5	1,75	2,1	1,93	5,6	0,56	0,52
8	C	5	1,4	1,4	1,4	4,2	0,59	0,53
9	C	6	2,1	1,05	1,58	5,4	0,57	0,52
10	C	10	1,8	1,7	1,75	8,6	0,55	0,55

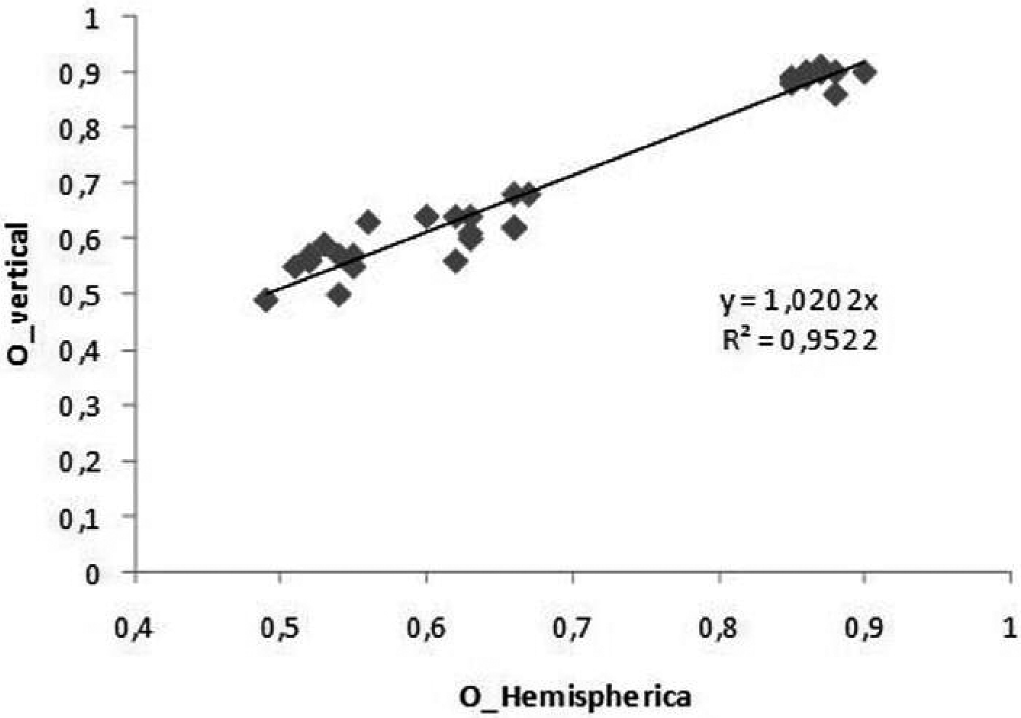


Figure 28. Comparison of degree of obstruction obtained for oak with both methods of photography

As was the case for the chestnut, the most significant allometric variables which best explain the modeling of the crown in its growth are the DBH and Dc, as can be appreciated in figure 29.

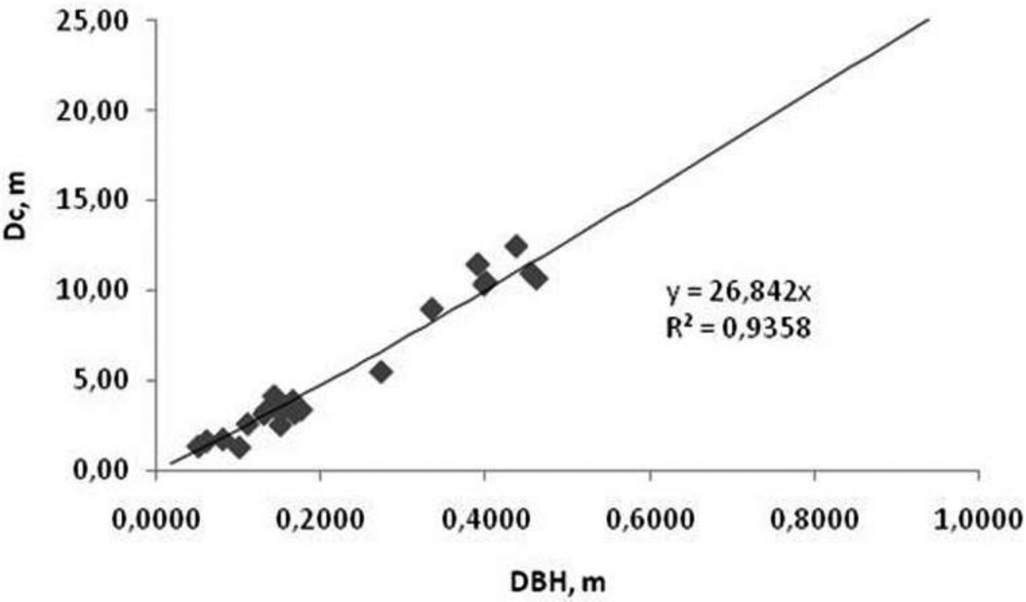


Figure 29. Exponential trend of the allometric variables of significance in the growth of the tree canopy in oak

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 (Figure 30). This reinforces the idea of its usefulness in integration research, as was the case with chestnut.

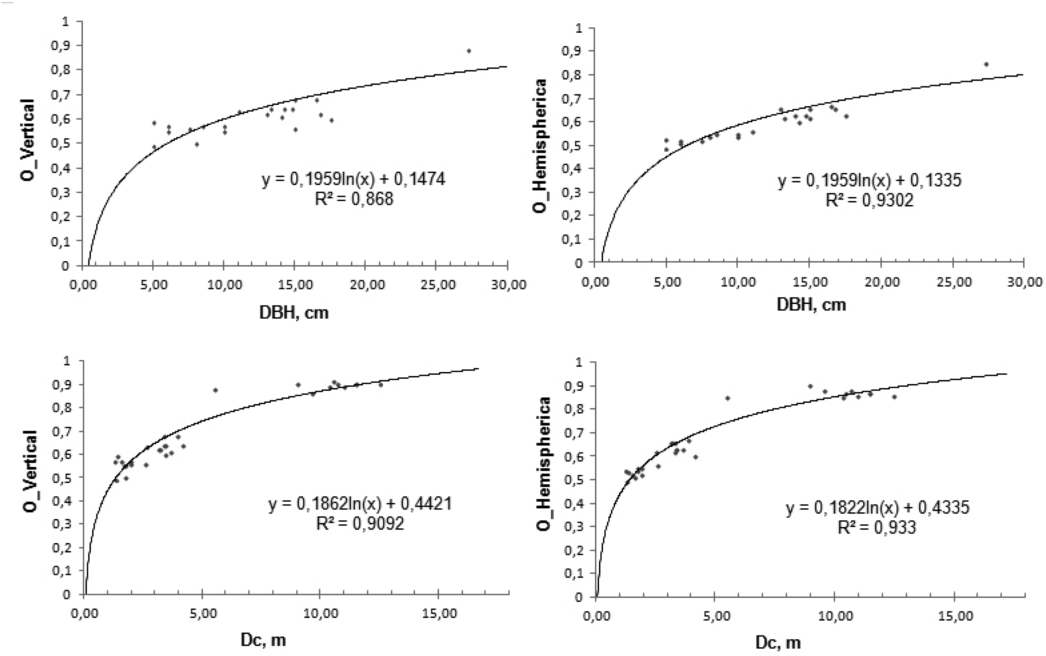


Figure 30. Logarithmic relationship of the models to estimate the filtering capacity of chestnut, starting from DBH and Dc, for both types of photographic acquisition

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 (Figures 26. and 29.), 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.

In the light of the results of the statistical analysis established between allometric relationships and the mean canopy concealment in trees under study, tables 8. and 9. 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 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.

3.2. ASSESSMENT OF PLANT SCREENS OF VARYING HEIGHTS AROUND BUILDINGS TO IMPROVE THEIR INTEGRATION IN THE LANDSCAPE

3.2.1. STATISTICAL METHODOLOGY (1)

The effect of the two factors: height of vegetation around the building, and that of the respondent's country of origin, over the variable dependent of the respondents was assessed by means of a two-way repeated-measures ANOVA taking the 24 infographs as the repeated measures. The fact that the infographs were presented randomly minimizes the errors of the sampling the directed response patterns (Stamps & Nasar, 1997; Barroso *et al*., 2012).

The normality analysis was performed by means of the Kolmogorov-Smirnov test. The a posteriori comparisons of the average values should the ANOVA be significant were performed through the Bonferroni test. They were considered significant when $p \leq 0{,}05$. The statistical analyses were carried out with the SPSS 19 © statistical software.

3.2.2. SPANISH PREFERENCES

The respondents in Spain consulted on the rating of the three vegetation heights around the building considered that a exceedance of 0 to 50% of the vegetation compared to building height is the response with greatest weight. The lowest rated scale is that of non-exceedance of the vegetation compared to building height. Regarding the exceedance of the vegetation by over 100% of the building height, it is at a mid-way point on the rating scale, although with no statistical difference in terms of the intermediate vegetation height, or at the no-exceedance extreme (Figure 31).

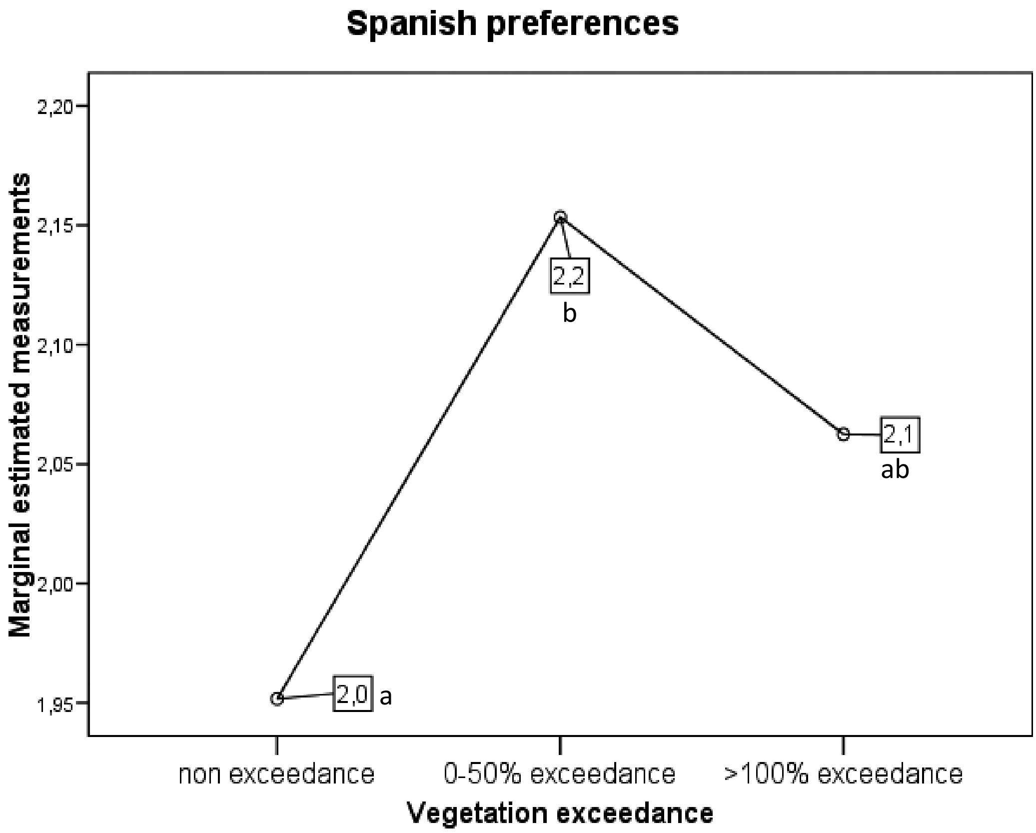


Figure 31. Interaction graph of vegetation screen average height preference around the building, by origin of the respondent (Spain). Different letters indicate significant differences; identical letters indicate similarity (*Bonferroni* Test)

As shown in figure 31, the respondents in Spain prefer there to be vegetation behind the building; the response with greatest weight is a vegetation height exceedance of 0-50% and < 100%. The lowest rating went to non-exceedance of the vegetation regarding building height, although this was not significantly lower than the extreme exceedance >100%.

3.2.3. SWEDISH PREFERENCES

The respondents in Sweden consulted on the rating of the three vegetation heights around the building considered that a exceedance of 0 to 50% of the vegetation compared to building height is the response with greatest weight. This coincides with the results obtained from the respondents in Spain. On the other hand, the lowest rated scale is that of exceedance of the vegetation <100% compared to building height. The non-exceedance of the vegetation compared to building height gives values similar to the exceedance from 0% to 50% of the vegetation compared to building height. And so this is the response with the second greatest weight, as is shown in figure 32. As for the extremes of vegetation height compared to the building, the respondents in Sweden prefer the vegetation not to surpass the building height by more than 100%, relative to the height of the building.

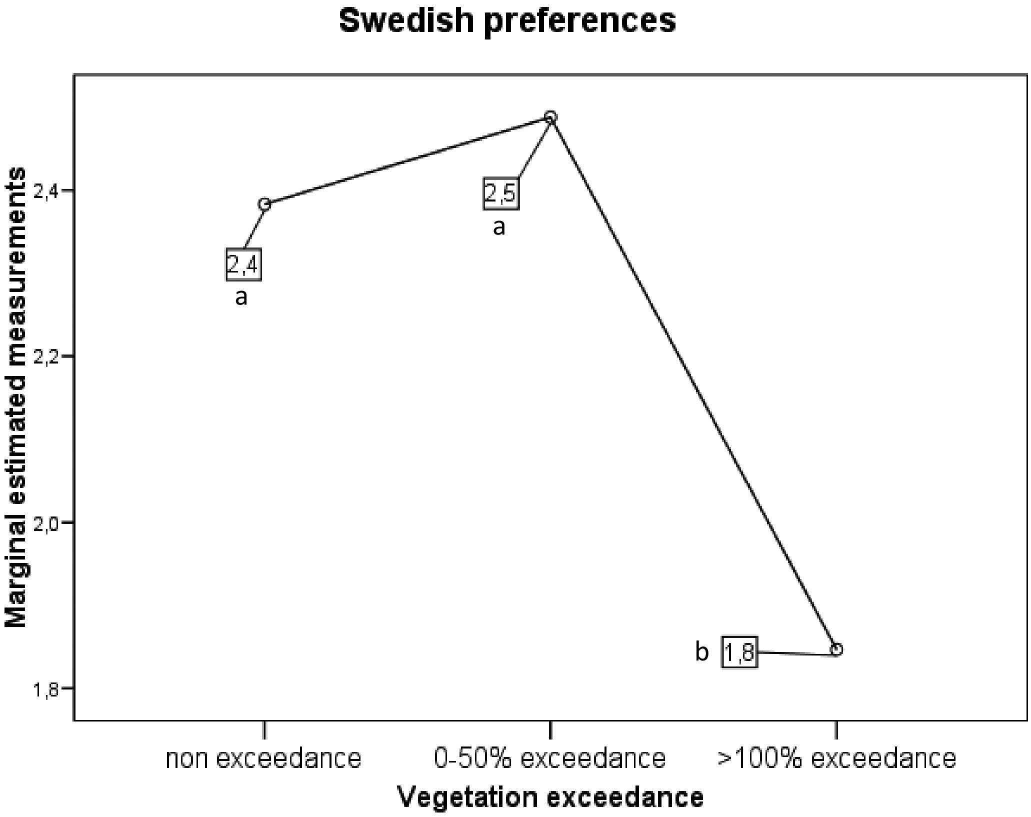


Figure 32. Interaction graph of plant screen average height preference around the building, by origin of the respondent (Sweden). Different letters indicate significant differences; identical letters indicate similarity (*Bonferroni* Test).

3.2.4. CONJOINT ANALYSIS OF DATA (1)

At this stage, a comparison took place of the average of the responses in both countries on the effect of vegetation height around the building. The exceedance from 0 to 50% of the vegetation regarding building height is the answer with greatest weight for respondents in both countries. Although as figure 33 shows, the respondents in Sweden rate considerably higher this height ratio than the Spanish.

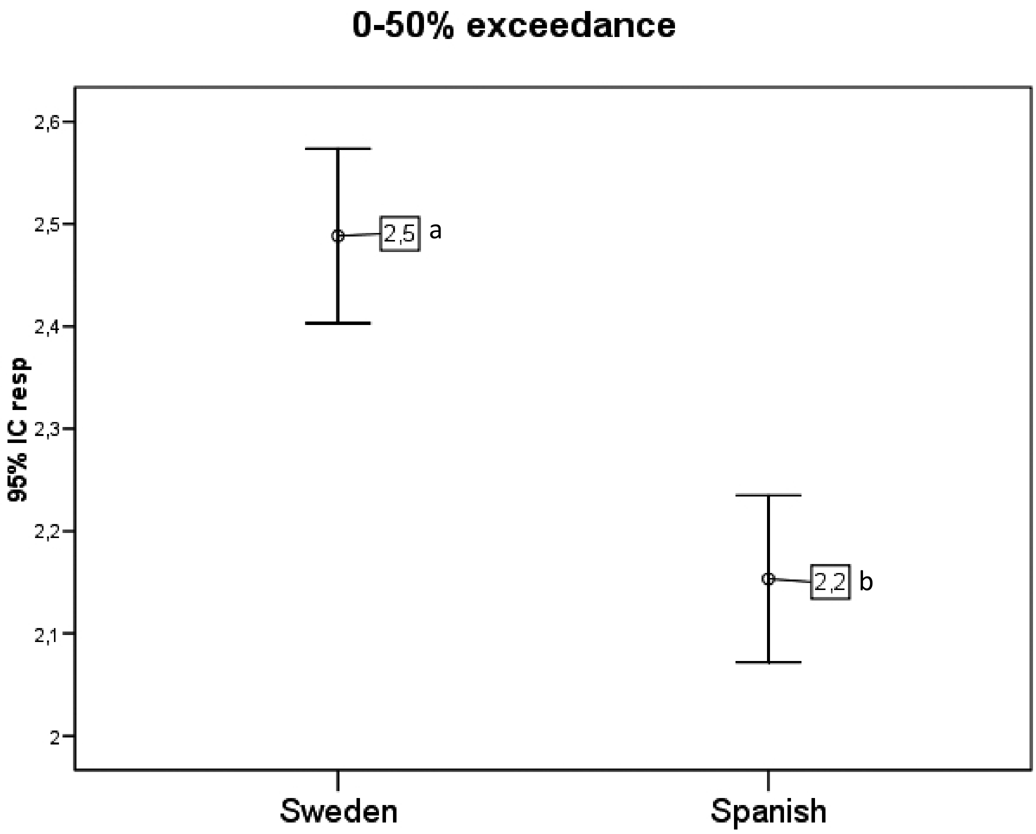


Figure 33 . Error bar chart comparing the average of the responses in Sweden and in Spain on the effect of vegetation exceedance from 0-50% relative to building height (95% Confidence interval). Different letters indicate significant differences.

Nonetheless the Spanish and the Swedes differ in the two extremes proposed in the survey. Thus, in the light of the results obtained from the Swedish respondents, given the choice of over 100% vegetation exceedance of the building height, and on the other hand non-exceedance of the vegetation compared to building height, the Swedes prefer the vegetation not to exceed the height of said building. Meanwhile the Spanish university students choose the opposite: given the choice, they prefer there to be vegetation behind the building, rather than an absence of this vegetation regarding building height (Figure 34).

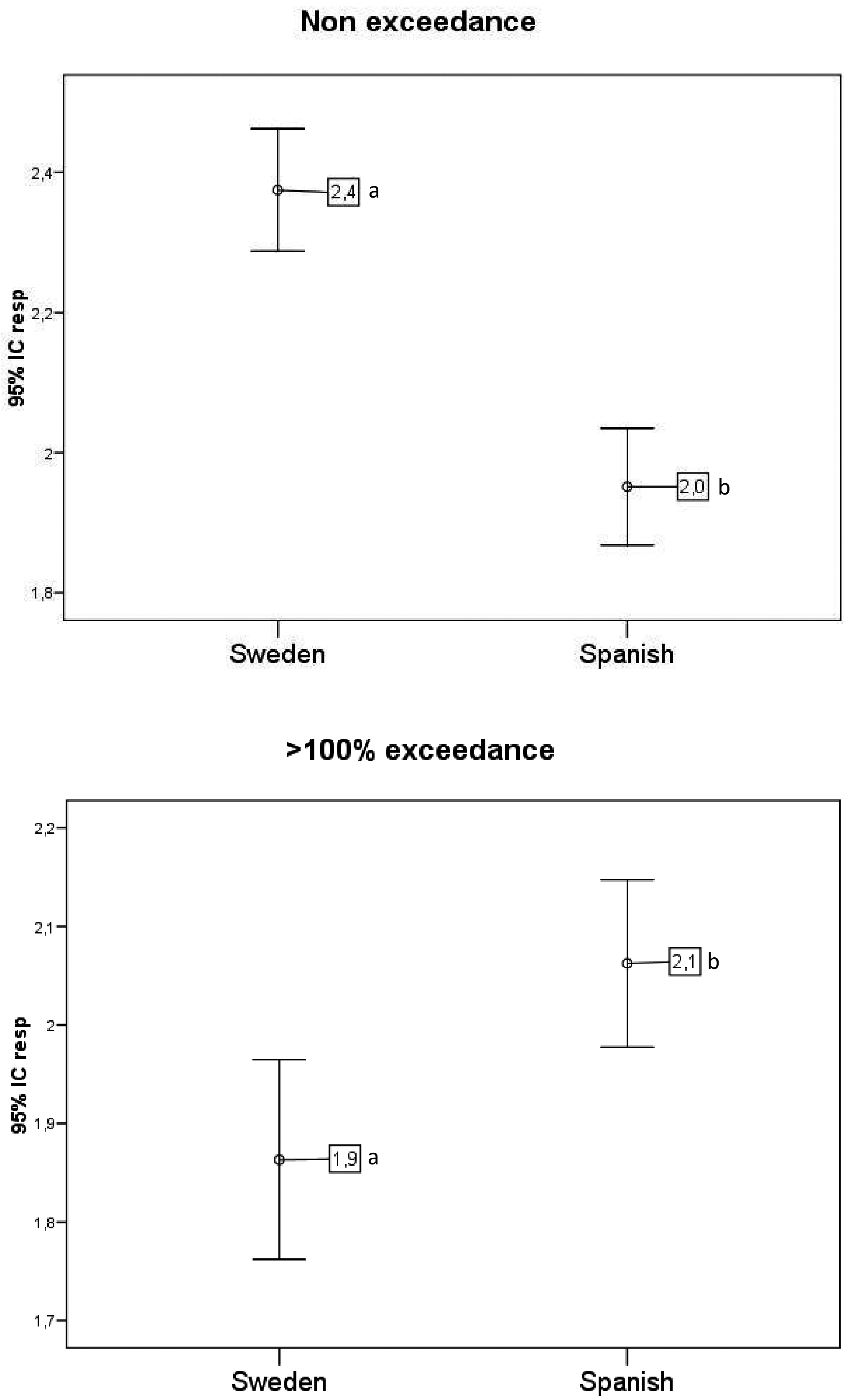


Figure 34. Error bar chart comparing the average of the responses in Sweden and in Spain on the effect of vegetation non-exceedance (up) and exceedance < 100% relative to building height (down) (95% Confidence interval).Different letters indicate significant differences.

There were five response options for the respondents (Very bad, Bad, Acceptable, Good and Very Good), as was explained in 2.3.1. However, for the analysis of results we have opted for grouping the responses into three classes: «*Very bad and Bad, Acceptable* y *Good and Very Good*» (García *et al*., 2003; García *et al*., 2010) (Figure 35).

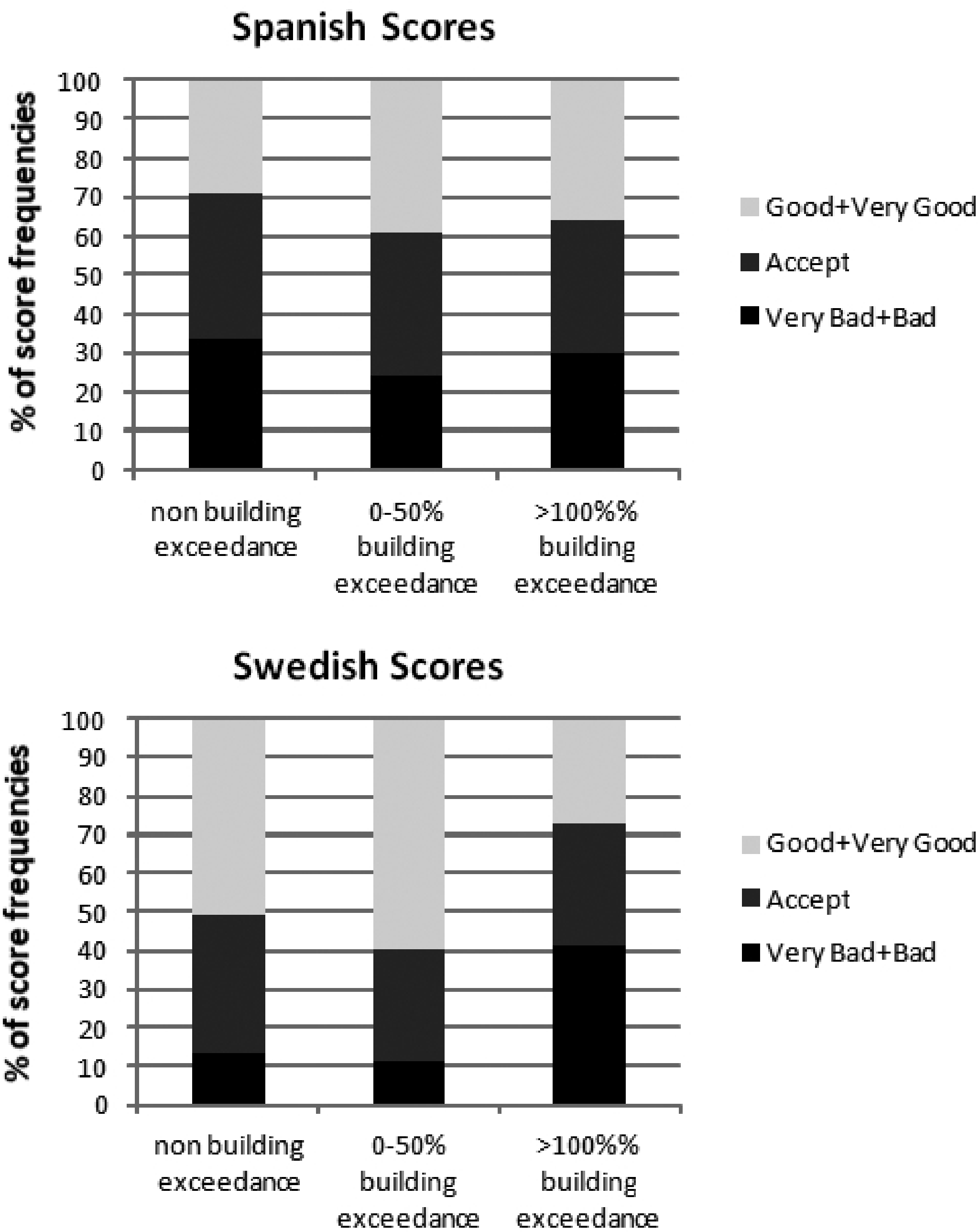


Figure 35. Effect of vegetation scale behind the building. The two graphs show the respondents' preferences in Spain (up) and in Sweden (down).

Figure 35 shows the preferences of the respondents in Spain and in Sweden, in terms of the use of different vegetation scales behind the building to improve its integration in the landscape.

Exceedance of 0 to 50% of the vegetation compared to building height gives results in which the responses with greatest weight are *Good* and *Very Good* for the respondents in Spain, coinciding with the respondents in Sweden. Meanwhile, the non-exceedance of vegetation compared to the building offers results where the significant responses are *Good* and *Very Good* for the respondents in Sweden and the responses with greatest weight within those of the respondents in Spain are *Acceptable, Bad* and *Very Bad*. Respondents in Spain rate vegetation exceedance of over 100% of the building height as a majority of *Very Good, Good* and *Acceptable.* On the other hand the most significant responses for the respondents in Sweden are *Bad* and *Very Bad.* (Figure 35).

This difference in the scale extremes proposed for the study could be due to the traditional relationship of each country to nature and environment (González-Canales *et al*., 2010). The landscape in Sweden is characterized by immense forests in which buildings exceeding the height of the native trees are seldom seen. Therefore, the Swedes may be finding that the non-exceedance of the vegetation is something different and striking, since it is out of the usual in their setting. However the students interviewed in Extremadura University prefer there to be vegetation behind the building, and the more the better, as it is uncommon (Berlyne, 1972; Nasar, 1984).

3.3. THE APPLICATION OF SCREENS OF NATIVE VEGETATION TO LESSEN IMPACT ON THE LANDSCAPE: METHODOLOGY AND CASE STUDIES

3.3.1. STATISTICAL METHODOLOGY (2)

The replies of the respondents are the dependent variable of the study; its ascending ordinal character permits a continuous analysis of the data (Kendrich, 2005). Thus, as well as the frequencies observed, the averages of the respondents' preferences were also determined for each photo. The type of vegetation (1=tree, 2=climber), the degree of filtering (None=0%, Medium=40-50%, High=70-80%), and the origin of the respondent (1=university student or 2=local), are the independent variables or study factors. The aim is to analyze if these factors carry weight in the dependent variable.

To these ends, two types of analysis are possible with the characteristics of the variables of work: 1) analysis of variance of repeated measurements (since all the respondents see the total of 24 cases) and 2) analysis of frequency by type of response (*Chi-squared* test by means of the use frequency graphics). Both analyses have a complementary character:

1) With any possible main effects and interaction effects between the study factors and the variable response are detected. This will make it possible to simplify the study by ruling out any factors that carry no statistical weight in the phenomenon, should there be any
2) With frequency graphics or histograms will itemize only the consistent effects discovered in 1).

3.3.2. FACTORIAL ANALYSIS OF REPEATED MEASURES (MANOVA)

The average of the response was analyzed with a factorial ANOVA: [vegetation type (2) x degree of filtering (3) x origin of respondent (2)]. The first two variables are subject to an analysis of repeated measures (*intra*-subject analysis), while the type of respondent comprises an analysis of *inter*-subject classic variance).

Those factors which affect the responses with statistical weight are analyzed in depth by means of *post hoc* analysis (*Bonferroni* test). This makes it possible to locate where the significant differences really arise within the categories of each factor, and to detect, among other things, if intermediate filtering percentages are significantly more badly evaluated than high percentages, or the absence of vegetation. Possible interactions between factors (e.g. vegetation type and degree of filtering) can also be analyzed with this sort of test.

The size of the effect of the significant results is also a very commonly used statistical indicator in visual impact studies. In this sense, the *d* of Cohen measures the force with which a phenomenon is produced. This indicates not only if two photos or scenarios have significant differences ($p<0,05$), but also how different they are. The value of $d>0,2$ is accepted by the scientific community as a good threshold for distinguishing visual impact factors of relevant weight (Stamps III, 1997).

In relation to the above, the MANOVA results with the study data prove that vegetation type, degree of filtering and origin of respondent have a significant partial main effect in the response. Thus, generally speaking, the presence of tree vegetation is more highly rated than the existence of climbing plants ($p<<0,01$; $d=0,63$), the degree of filtering is always valued more highly in ascending order ($p<<0,01$; $d=0,7$), and university students rate slightly better than the locals ($p<<0,01$; $d=0,8$). However, no interactions are observed between origin of respondent and the study factors, which means that, even if the university students have a significant tendency to value higher, there has been a similar response pattern according to the degree of filtering and vegetation type (data not shown). This means that a global response pattern can be assumed, whatever the origin and academic background. Similar results have been obtained by Coeterier (2002), assuming that familiarity with the scenarios presented has a slightly negative effect on the assessments by local people, even though this is not enough to affect the global response pattern of the remaining study variables.

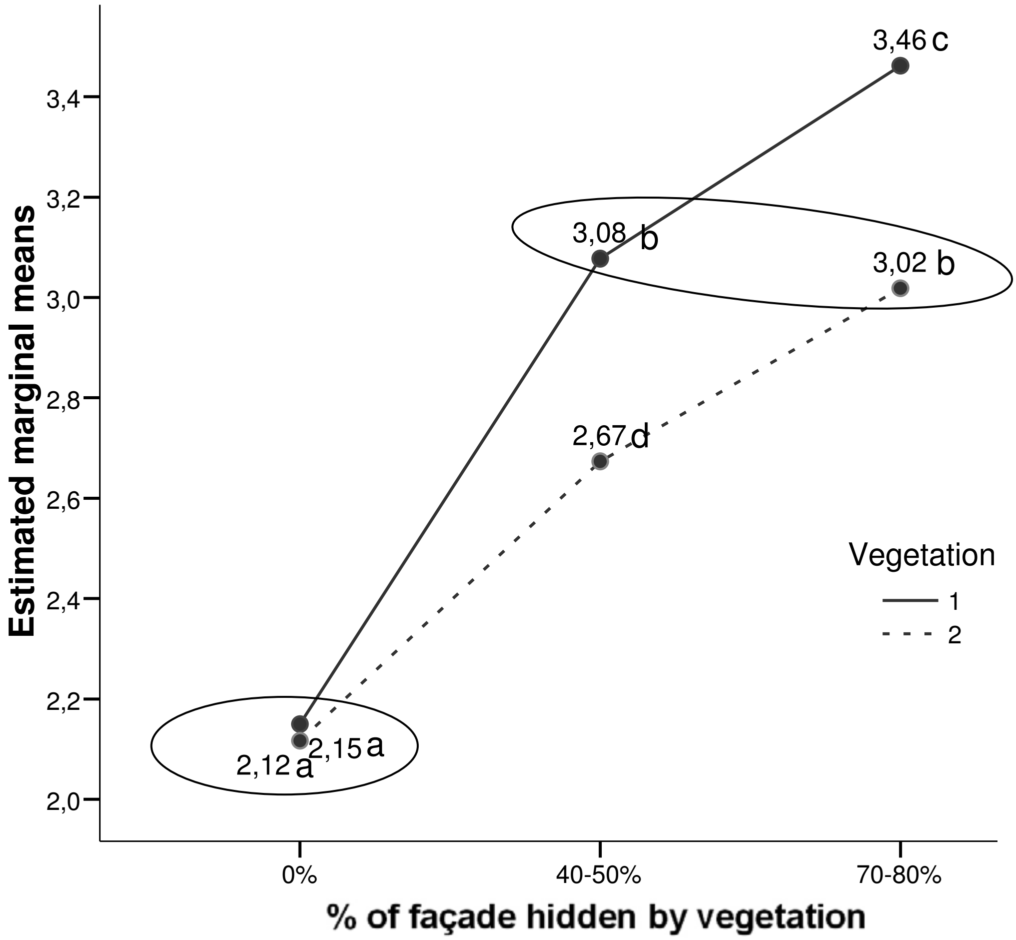


Figure 36. Graph of interaction of averages of Filtering x Vegetation.

Once this point has been reached, the origin of the respondent is assumed to be not relevant in the vegetation filtering analysis. Nevertheless, filtering and vegetation type do have an interacted effect, as can be seen in figure 36.

1=tree; 2=climbing plants. Different letters indicate significant differences; identical letters indicate similarity (*Bonferroni* Test). (Data from MANOVA: F [1.9, 120]=13.15; p<<0.01; d=0.41).

In this sense, as well as the aforementioned, (better evaluation of trees than climbers), we can see that the significant differences between the degree of filtering are only to be found in phases 2 (40-50%) and 3 (70-80%) of plant coverage. This means that as the degree of filtering increases, so do the differences in acceptation increase significantly, the buildings with a high filtering coverage (70-80%) in both vegetation types being the most acceptable (Figure 36). It seems logical to think that in phase 1 (absence of filtering), the response pattern is similar for both vegetation types, and so the valuation averages converge in the graph of figure 36, while they are also the cases of lowest value (2.1), or worst acceptance. Another interesting effect is produced when a comparison is made of the medium filtering averages (40-50%) of the trees (3.08, Figure 36), with the high filtering averages (70-80%) of climbing plants (3.02, Figure 36). Both values are statistically equal, around the score category 3=”acceptable”. The interpretation of this result would seem to imply that, in order to attain positive integrations over 3, in a scale from 1 to 5, two combinations could be used: either trees with medium filtering threshold, or covering plants which density the façade to a high percentage. The importance of this data can be transferred to town-planning management, since the plant type or species and its degree of filtering should not be combined at random, as shown in the results. Further research with other species could broaden these results.

On the other hand, the size of the effect of the interactions between vegetation and filtering d=0.41, is high enough (d>0.2), to be taken into consideration. This also gives relevance to this work, insofar as with a relatively small sample of respondents n=66, pronounced effects are obtained on filtering and vegetation type in front of a façade. Increasing the sample would not provide a higher significance level nor more consistency to the results already presented here. This leads us to think that both variables (vegetation type and degree of filtering) carry much weight in the visual effect of a façade, which could be generalized for any average respondent.

3.3.3. ANALYSIS OF FREQUENCIES

The Chi^2 test confirmed the paired differences between the five response types (from Very Bad to Very Good), and the three degrees of plant density (data not shown) (Figure 37). These analyses no longer consider the effect of the respondent, going on the results presented in Section 3.3.2. In this sense, it is clear that if all the façade is visible, then the evaluation of the whole drops; instead the best situation is when there are façade vegetation coverages well over 50%, and this occurs whatever the vegetation type, though climbers have a lower overall evaluation (Figure 37).

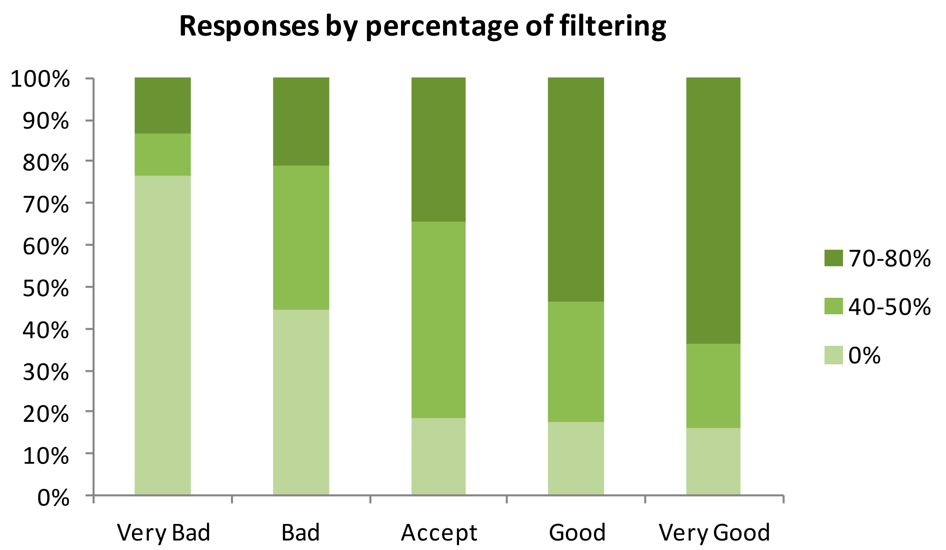


Figure 37. Percentage of total responses by degree of filtering. (chi^2 [8, 1584]=386.3; p<<0.01).

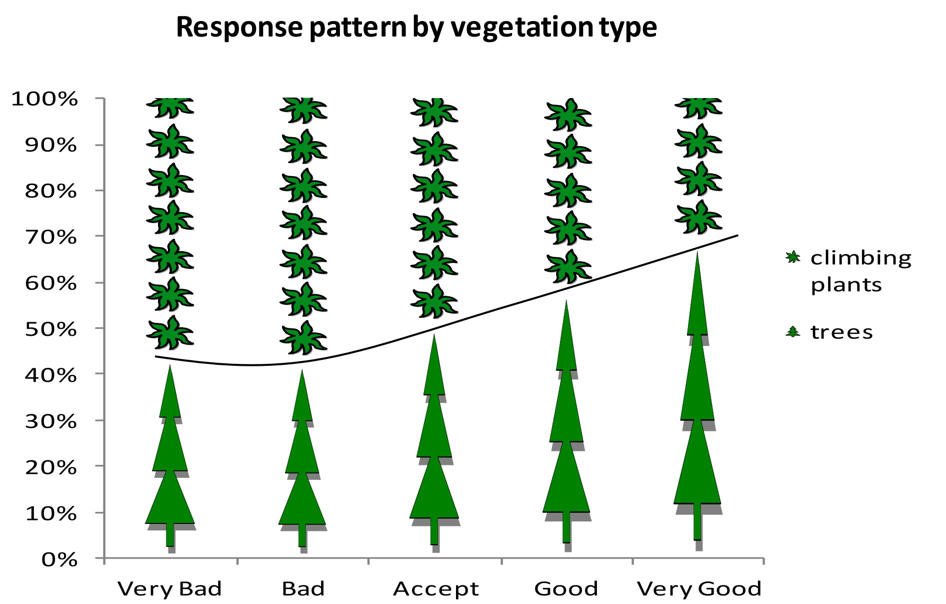
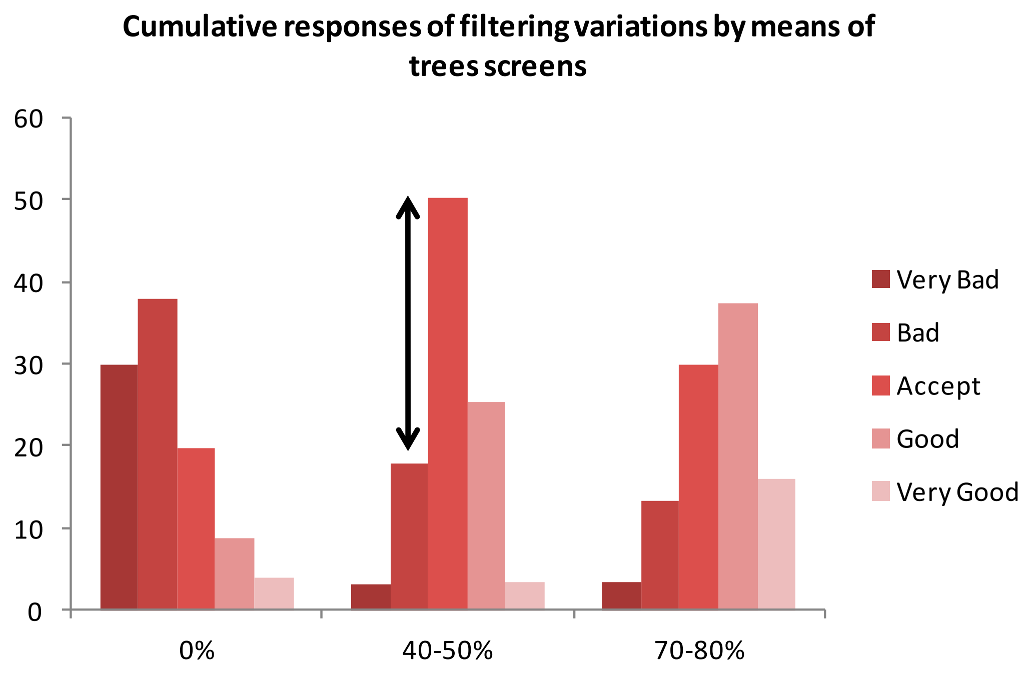


Figure 38. Response pattern by vegetation type. (Chi^2 [4, 1584]=34.93; p<<0.01).

The screening around this threshold (50%) clearly raises the likelihood of finding evaluations as a minimum of "Acceptables" in the case of trees (Figure 38), although for the climbers we should once again increase to 70-80% of plant coverage so as to attain good probabilities of acceptance (Figure 39).



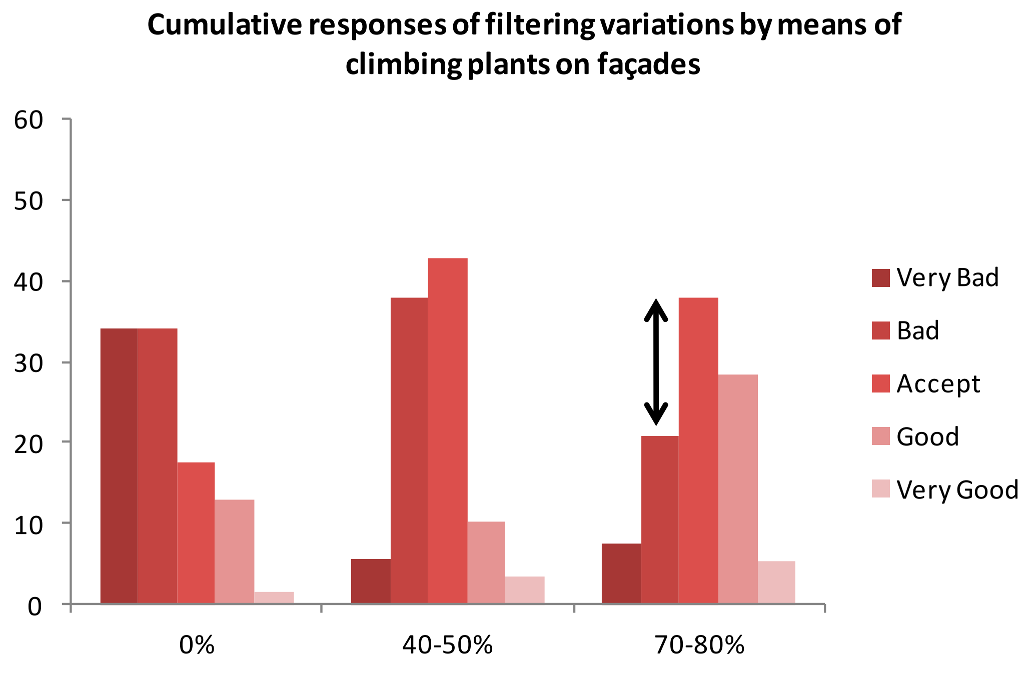


Figure 39. Responses by degrees of filtering and vegetation type: a) case of trees (Chi^2 [8, 792]=262.54; p<<0.01); b) case of climbers (Chi^2 [8, 792]=162.53; p<<0.01).

3.4. VISUALIZATION OF 3D VIDEOS AND SCENARIOS FOR ASSESSMENT OF VARIOUS VEGETATION SCREENS FOR THE INTEGRATION OF BUILDINGS IN THE LANDSCAPE

3.4.1. STATISTICAL METHODOLOGY (3)

The design of the Latin square which is extracted from table 7 is characterized by the fact that every cell or intersection in the matrix represents variations on three factors of analysis: tree density (rows), species around the house (columns) and speed of itinerary (cells).

Furthermore, the Latin square implies a random design of three independent factors at a minimal sampling cost. Thus the design is suitable for factorial analysis of variances (ANOVAS). For this purpose the statistical software SPSS 19 © was used. Moreover the strength of this analysis for the current work was reinforced with the random presentation of three video per respondent which imply a variation in the three variables under study (density, species and speed). This means minimizing sampling errors and directed response patterns (Stamps & Nasar, 1997; Barroso *et al.*, 2012).

3.4.2. ANALYSIS OF DATA: SOUTH HUELVA

Here the responses of eighty-five respondents were analyzed. The respondents had five response options (Very bad, Bad, Acceptable, Good and Very good), as was explained in the previous section. ANOVA was significant only for the factor of density (Table 10)

Table 10. Test of the inter-subject effects of dependent response variable to the question, in which only the factor of density has been significant

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power (a)
Corrected Model	157,659(b)	6	26,277	37,012	,000	,472	222,073	1,000
Intercept	3052,326	1	3052,326	4299,387	,000	,945	4299,387	1,000
Speed	,987	2	,493	,695	,500	,006	1,390	,167
Density	156,563	2	78,282	110,264	,000	,471	220,529	1,000
Vegetation	,594	2	,297	,418	,659	,003	,837	,117
Error	176,066	248	,710					
Total	3475,000	255						
Corrected Total	333,725	254						

Dependent Variable: Of the answers to question 1
a Calculated with alpha = ,05
b R square = ,472 (R corrected square = ,460)

This indicates that neither the vegetation type nor the speed of movement around the itinerary, and therefore the type of associated activity, have had any weights in the assessment of the videos. The only positive effect has been concealing the building with vegetation, and this would seem to be independent of the layout of the vegetation. In other words, it does not matter if the screen is linear or irregular. The latter can be deduced from *post-hoc* comparisons made between the categories of the density factor and in which the high irregular density has the same acceptance as high linear density (Figure 40). The opposite applies to low density, which is by far the worst assessed density factor category (Figure 40).

On the other hand, for the main objective of this work, what does seem to have worked properly is the level of photo-realism displayed. Although a large part of the respondents would improve the quality of the videos, there is also a significant percentage of people who would not change anything, in spite of noticing that the videos are simple (Figure 41). And so, without the need for great realism, the videos shown have been enough to find significant differences in the analyses of the question asked, as main objective of this study. Therefore, a large budget for equipment and resources does not seem necessary to analyze the preferences of landscape via Hyper-realistic quality simulations. (Paar, 2006).

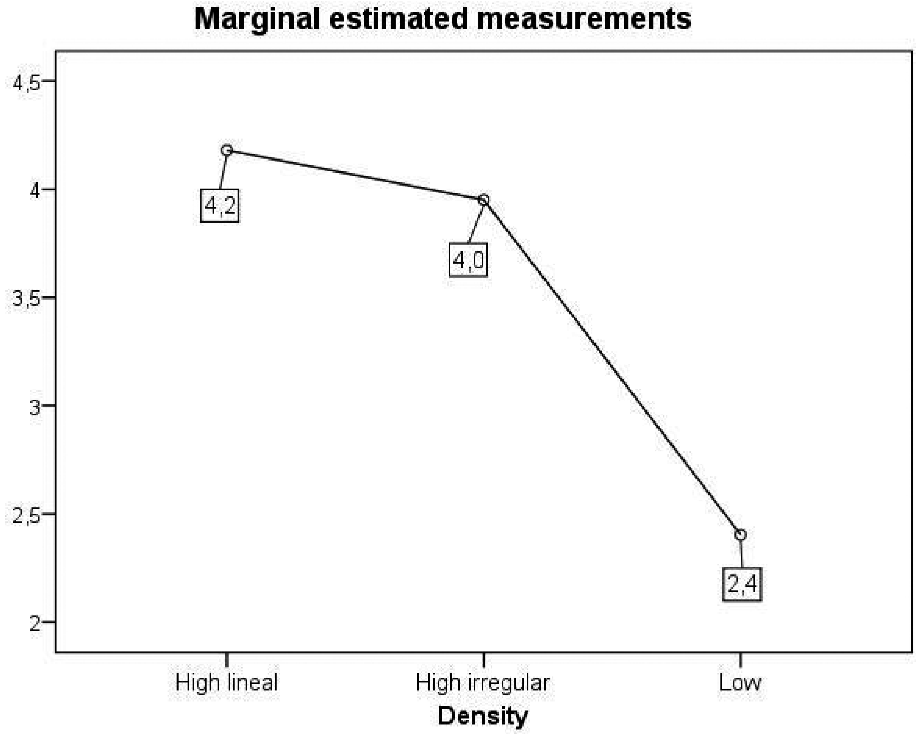


Figure 40. Comparison of the assessment averages (question 1) by density type (Huelva).

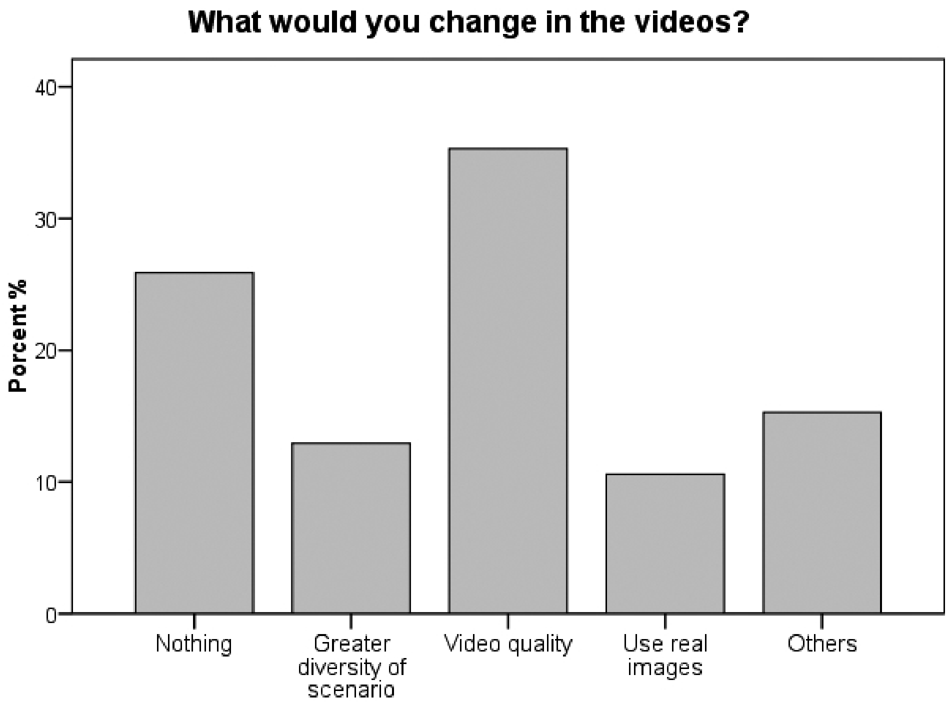


Figure 41. A count of the responses to the final open-type question. The answers have been summed up in five categories according to the most common responses (south Huelva). Under the heading “Others” the most common are: change the speed, duration of the video, possibility to interact and move around the itinerary with freedom of movement (360º turns).

3.4.3. ANALYSIS OF DATA: NORTH EXTREMADURA

Here the responses of 84 respondents have been analyzed. The respondents' options of response were five, the same as for those of south Huelva. The results were similar to those obtained for Huelva, since once again only density carries a significant weight in the assessment of scenarios or videos (Table 11).

Table 11. Test of the inter-subject effects of dependent response variable to the question, in which only the factor of density has been significant

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power (a)
Corrected Model	204,087(b)	6	34,014	45,071	,000	,525	270,427	1,000
Intercept	2823,013	1	2823,013	3740,660	,000	,939	3740,660	1,000
Speed	1,638	2	,819	1,085	,340	,009	2,170	,239
Density	200,876	2	100,438	133,086	,000	,521	266,172	1,000
Vegetation	,917	2	,459	,608	,545	,005	1,216	,151
Error	184,897	245	,755					
Total	3490,000	252						
Corrected Total	388,984	251						

Dependent Variable: Of the answers to question 1
a Calculated with alpha = ,05
b R squared = ,525 (R squared corrected = ,513)

Post hoc comparisons of analysis also reveal that the high irregular density is as accepted as high linear density. The opposite is true with low density, which is by far the worst assessed density factor category, coinciding with the results obtained for south Huelva study area (Figure 42).

Regarding the final question, once again changing nothing, or at most changing the quality of the videos, is the most common response (Figure 43). However in the case of north Extremadura the frequencies are inverted: and the number of cases with no changes is greater. Therefore, the results for the case of Huelva could indicate that the videos have been perceived with more simplicity, although in any case, and in both zones, the simulation seems sufficient for the objectives of the work.

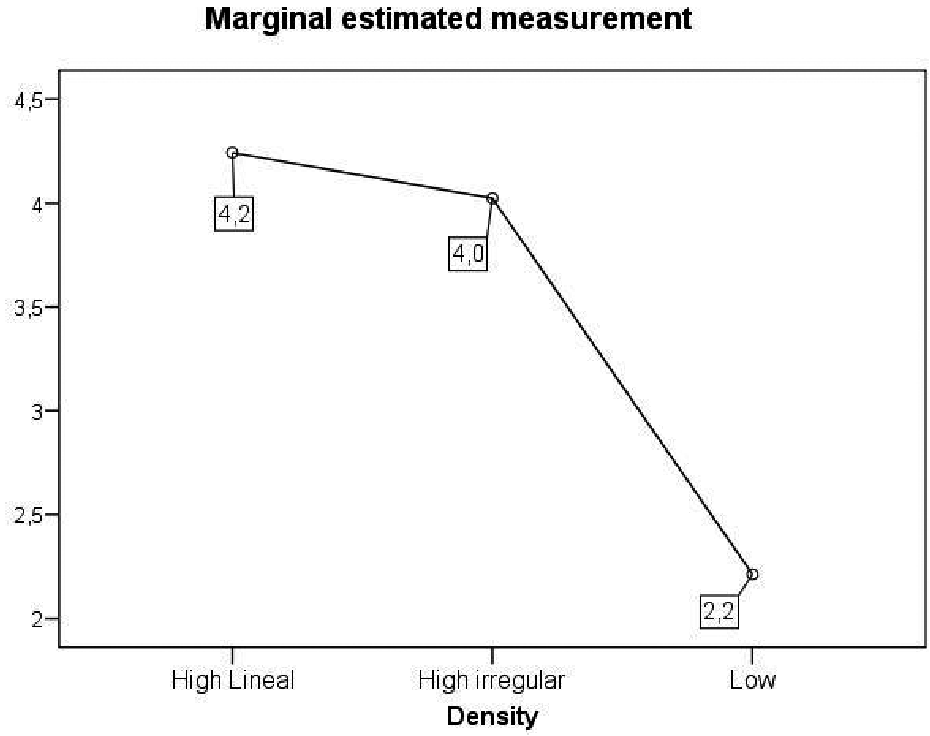


Figure 42. Comparison of the assessment averages for type of density (north Extremadura).

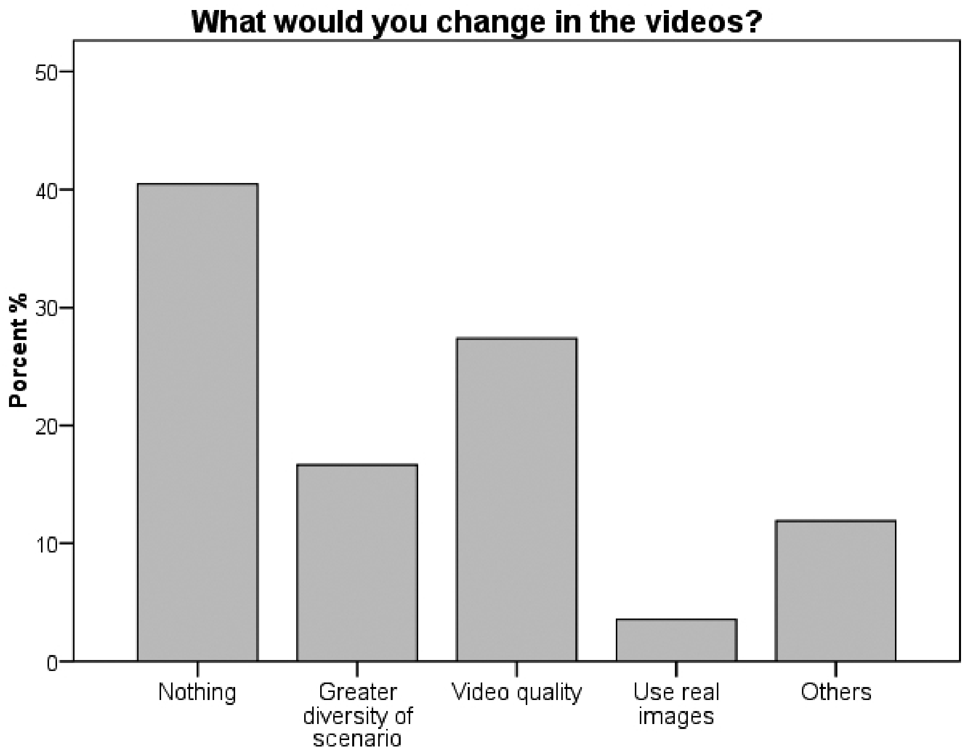


Figure 43. A count of the responses to the final open-type question. The answers have been summed up in five categories according to the most common responses (north Extremadura). Under the heading “Others” the most common are: change the speed, duration of the video, possibility to interact and move around the itinerary with freedom of movement (360º turns).

3.4.4. CONJOINT ANALYSIS OF DATA (3)

Finally, the results obtained in an ANOVA including the two study areas are shown to have an almost identical response factor, thus corroborating the results obtained in sections 3.4.2. and 3.4.3. Both samples show almost identical rating averages for the question in the assessment survey for the two scenarios under study (Table 12).

Table 12. Test of the inter-subject effects of dependent response variable to the question, in which only the factor of density has been significant

	Sum of Squares	df	Mean Square	F	Sig.
Inter-grupos	,000	1	,000	,000	,986
Intra-grupos	722,710	505	1,431		
Total	722,710	506			

In the light of the results obtained, out of the three variables under study in both studies, density is the only one that is significant (Figures 40 and 42). Therefore, in the analyses performed, neither the vegetation layout, nor the speed, nor therefore the type of associated activity has been significant (Tables 10 and 11).

In view of the results obtained, only the concealment of the building has an influence in the respondents' assessment of both scenarios, whatever the species used for the purpose.

The answers to the open question asked in the survey shows that the level of photorealism in this work was suitable for the proposed purpose of the study (Appleton & Lovett, 2003). Although a large part of the respondents would improve the quality of the videos, there is also a significant percentage of people who would not change anything, in spite of noticing that the videos are simple (Figure 41 and 43). And so, without the need for great realism, the videos shown have been enough to find significant differences in the analyses of the question asked, as main objective of this study. Therefore these results tie in with those obtained by other authors (Perkins, 1992; Paar, 2006; Cubukcu 2011), a large budget for equipment and resources does not seem necessary to analyze the preferences of landscape via Hyper-realistic quality simulations which may be in some cases counterproductive and surplus to the objective of the study.

The results obtained while comparing the answers about both scenarios have displayed similar answer tendencies (Table 12). Therefore, when it comes to assessing both scenarios, topography and the use of different tree species for woodland makeup, in which both scenarios differ, have not had a significant influence (Figure 23).

4. CONCLUSIONS

4.1. CONCLUSIONS

The main conclusions of this work on vegetation screen, to judge from the results obtained, are in line with those obtained by a research group on other similar projects. Furthermore, the practical and specific nature of the work carried out means that many of them are of direct assistance to architects planners, designers and technicians.

After the research carried out, the following conclusions have been reached, which can be classed in five thematic groups:

1. The criteria proposed for the use of vegetation screens to lessen the visual impact of buildings on the rural landscape (corresponds to objective 1 laid down en section 1.5. of the current work):

- The use of vegetation to filter the sight of the building always improves the assessment of integration.
- The use of vegetation with an intermediate degree of filtering on the facades of the building (40-50%) raises the probability that the perception of the same goes from Bad or Very bad to Acceptable, at least.
- A greater percentage of vegetation filtering (around 70-80%), but below total concealment, always improves, so raising the probability that the integration assessment is Good or Very Good.
- Generally speaking, trees laid out as a screen improve integration more than climbing plants on the facades.
- The building must not exceed the average height of the vegetation that surrounds it. In this case an option is to place screen behind and to the sides to prevent the building breaking the skyline.
- When the vegetation behind a building exceeds the relative height of the building by 0-50%, the probability increases of obtaining an assessment of integration of Good or Very Good.
- The length of the vegetation barrier is to be longer than the length of the building to be concealed.

2. Regarding the estimation of optical porosity or canopy structure of the two tree species with hemispherical and vertical images (corresponds to objective 2 laid down in section 1.5. of the current work):

- It can be deduced from the comparison of hemispherical and vertical photographic methods to estimate the calculation of optical porosity in the tree species, that both methods are completely valid for measuring the degree of porosity of canopies of *Castanea sativa* and *Quercus pyrenaica.*
- The allometric variable that carries greatest weight in the modeling of canopy growth (Dcopa) is the diameter of the trunk at breast height (DBH). Both variables (Dcopa, DBH), have born significant weight in the search for models to estimate the filtering capacity by species according to growth
- These models found can be taken as useful tools to analyze the effect that partial concealment of the tree canopy by species has. There is a direct application for studies on landscape integration, as is the case of integration of buildings in the countryside.
- The fact that these models are so simple to apply means that it is possible, with only by measuring one parameter, (DBH, or Dcopa), to estimate the concealment capacity for the species under study with a high degree of accuracy.
- Likewise, the consistency of the methodology and protocols laid out here allow us to recommend its use in the search for models to estimate the filtering capacity in species others than those studied here.

3. Regarding the assessment of varying heights of vegetation screen behind the building to improve their integration in the landscape (corresponds to objective 3 laid down in section 1.5. of the current work):

- The introduction of vegetation that exceeds the height of the building, means the building’s scenic occupation is reduced. This makes the scale less perceptible, softening its negative impact on the landscape.

- The relative comparison of building volume with the scale of adjacent elements (trees and bushes) means that building heights do not contrast so sharply with the surroundings, and so impact is lessened.

4. Regarding the assessment of vegetation screen in front of a building to improve its integration in the landscape (corresponds to objective 4 laid down in section 1.5. of the current work):

- The use of vegetation to filter the view of the building, generally speaking and whatever the species under consideration, improves landscape integration.
- Vegetation species or type and its degree of filtering should not be combined at random. On a rating scale from 1 to 5, to reach positive integrations over 3, we can use two combinations: either tree species with average filtering thresholds (around 50%) or groundcover plants which densify the façade to a high percentage (around 80%) .

5. Regarding the visualization of 3D videos and scenarios for assessment of different vegetation screens for the integration of buildings in the landscape (corresponds to objective 5 laid down in section 1.5. of the current work):

- The proposed method based on the creation of 3D elements in SketchUp 8 Pro © and within the MDT created in ArcGis 10 © for the simulation of videos in the ArcScene module, from the point of view of an observer in motion at varying speeds has shown itself to be consistent and user-friendly enough to recommend its use in works with similar aims, from the perspective of landscape planning.
- The use of 3D modeling seems to be a useful tool to facilitate the integration of buildings in the landscape.
- In the scenarios of north Extremadura and south Huelva, of all the varying vegetation screens placed around a building, the one with highest scores is that of high density, whatever its layout.
- The use of vegetation improves the integration of buildings in the landscape. In fact the concealment of these buildings has been rated highly, since neither the species used to these ends nor the speed and

therefore the type of activity associated and topographical differences in in the two scenarios have been of significance in the analysis of the results obtained in this study.

4.2. FUTURE RESEARCH

Upon completion of this thesis, there are in-depth questions that have enough entity to generate future research line to continue and complete the results of this work. Among others, the following proposals are made:

I. Deepen the 3D modeling of the types of plant species commonly used to mitigate the visual impact of buildings in rural areas. Implementation of the models and their growth patterns in CAD and GIS programs capable of three-dimensional analysis. Adding the possibility to export the models generation codes as internal programming routines valid in both environments, usable by users familiar with them.

II. Generate an interactive virtual environment that allows respondents to modify the modeled scenarios and different elements, addition to allowing them to freely navigate inside the modeling space. Therefore, this would produce an exchange of ideas much more dynamic and would get the public to actively participate in planning and modifying their surroundings.

III. In light of the results obtained in the experiment II (explained in sections 2.2. and 3.2.) the respondents in both countries differ in the proposed extremes of vegetation scale around the building. Cultural aspects related to society-vegetation type could be one of the causes which explain this discrepancy. In any case more research along these lines is to be recommended, so as to delimit other possible causes, if such is the case.

5. ANNEXES

ANNEX I: HEMISPHERICAL PHOTOGRAPHY

ANNEX I: HEMISPHERICAL PHOTOGRAPHY

As explained in section 2.1, hemispherical photography is an accepted method which is frequently used in the scientific community to calculate light transmitted or intercepted by the tree canopy. It makes it indirectly possible to calculate the percentage of the canopy occupied by the foliage (Rich, 1990; Roxburch & Kelly, 1995; Valladares, 2006). The equipment used and the approach followed for hemispherical photographic captures are detailed below.

Figures 44 and 45 show the photographic equipment used for photo capture: a Nikon Coolpix 995 digital camera (Figure 44) and the tripod the camera platform rests on (Figure 45).

Figure 44. Nikon Coolpix 995 digital camera used for field work.

Figure 45. 1) Tripod the camera platform rests on, at a height of 1.5 m above the ground. 2) The digital camera and fisheye lens are fitted to the tripod

After performing the two previous steps (Figures 44 and 45), the camera is levelled using the lens platform. Thus, we can keep the camera horizontal to the ground, which is essential for then pointing the camera upwards. The camera and tripod are then pointed north with the help of a compass. The bubble level and the compass are circled in figure 46.

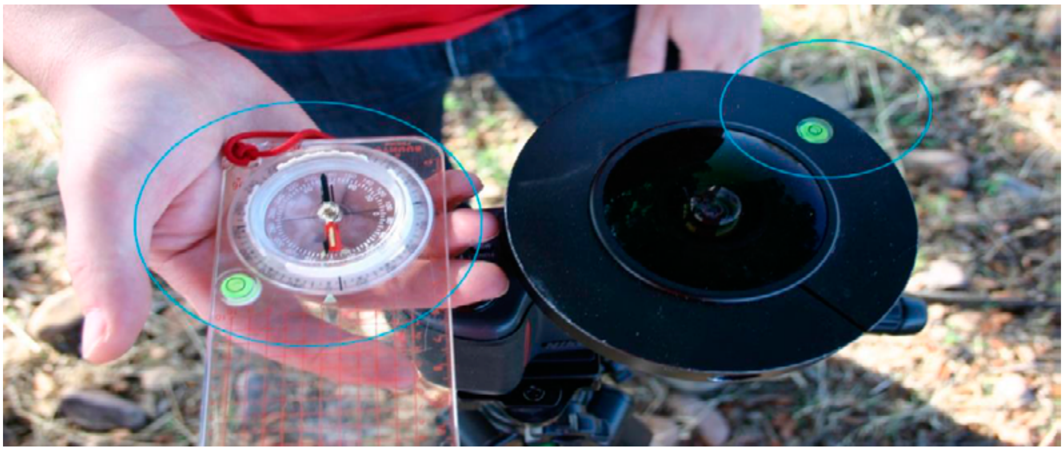


Figure 46. The compass pointing north and the fisheye lens leveled horizontally with the tripod are circled.

Finally the photos are taken of the various orientations of the tree. The photographer must always stay below the platform so as not to appear in the photo. (Figure 47).

Figure 47. Positioning the photographic equipment 40 cm from the trunk, and consulting the compass to point to geographic north.

The outcome is fisheye-type photographs, as can be seen in figures 48.

Figure 48. Photos taken of one of the trees under study following the protocol laid down: in the four orientations. All the photos are oriented towards geographic north.

ANNEX II: VERTICAL PHOTOGRAPHY

ANNEX II: VERTICAL PHOTOGRAPHY

The vertical photography method aims to quantify the degree of filtering from different orientations (as does the hemispherical photographic method explained in Annex I), observed from frontal view points and for an observer with an average height of 1.70 m. The study is repeated in the four cardinal points (N, S, E, and W).

The same camera was used to take these photos as was used for the hemispherical photos (Figure 49), at the height of an average observer, on a tripod and at 10 m from the tree trunk, to capture the whole of the canopy under study (Figure 50).

Figure 49. Nikon Coolpix 995 digital camara, used in fieldwork.

Figure 50. 1) Digital camera fixed on tripod. 2) Tripod on which the camera platform rests on at a height of 1.70 m above the ground. 3) Tape measure to measure the 10 m to the tree

The screen is fixed to lengths of PVS tubing, 1.50 m long. The maximum height of the structure ranges from 8 to 9.5 m, according to the height of the tree canopy. Once unfurled it is 2.4 m wide by 1.4 m high (Figure 51).

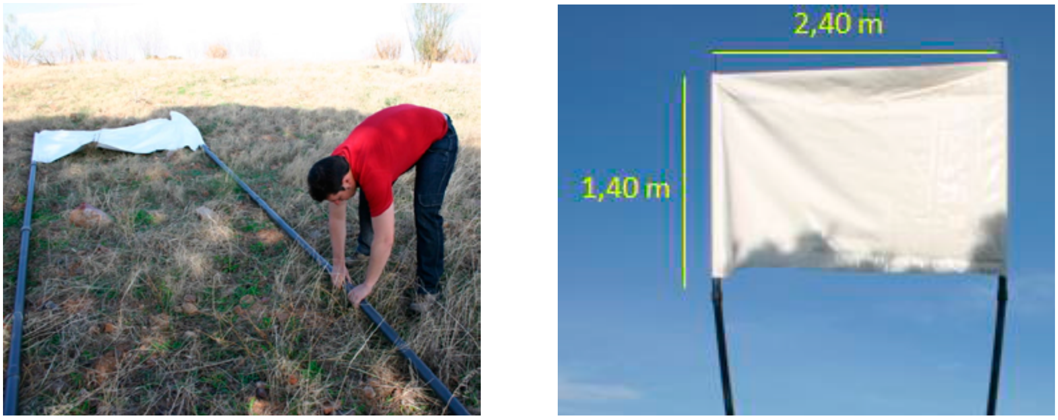


Figure 51. Left: fitting the screen to 1.5 m lengths of PVC tubing. Right: the unfurled screen which is 2.4 m wide by 1.4 m high.

Once the photos have been taken in the field as seen in figure 52, they are analyzed with SideLook v.1.1 software, Annex III, to be changed to black and white, and subsequently the pixels are counted using Adobe Photoshop CS5 ® Annex IV.

Figure 52. The screen is place behind the tree canopy and the photos are taken from the different orientations at 10 m from the tree trunk.

ANNEX III: SIDELOOK v.1.1. SOFTWARE

ANNEX III: SIDELOOK v.1.1. SOFTWARE

As was explained in section 2.1., the methodology proposed by Nobis & Hunziker in 2005 proved that the best way to obtain a threshold to convert photos to black and white is to work in the blue cannel of the visible spectrum. SideLook v.1. 1 software was designed for this purpose and is used in this experiment for the reasons outlined.

This software is relatively simple to use. It only takes three steps, see below, to analyze the sample photo.

The first step is to open the image we wish to analyze, selecting the *Open picture* option on the *File* menu (Figure 53).

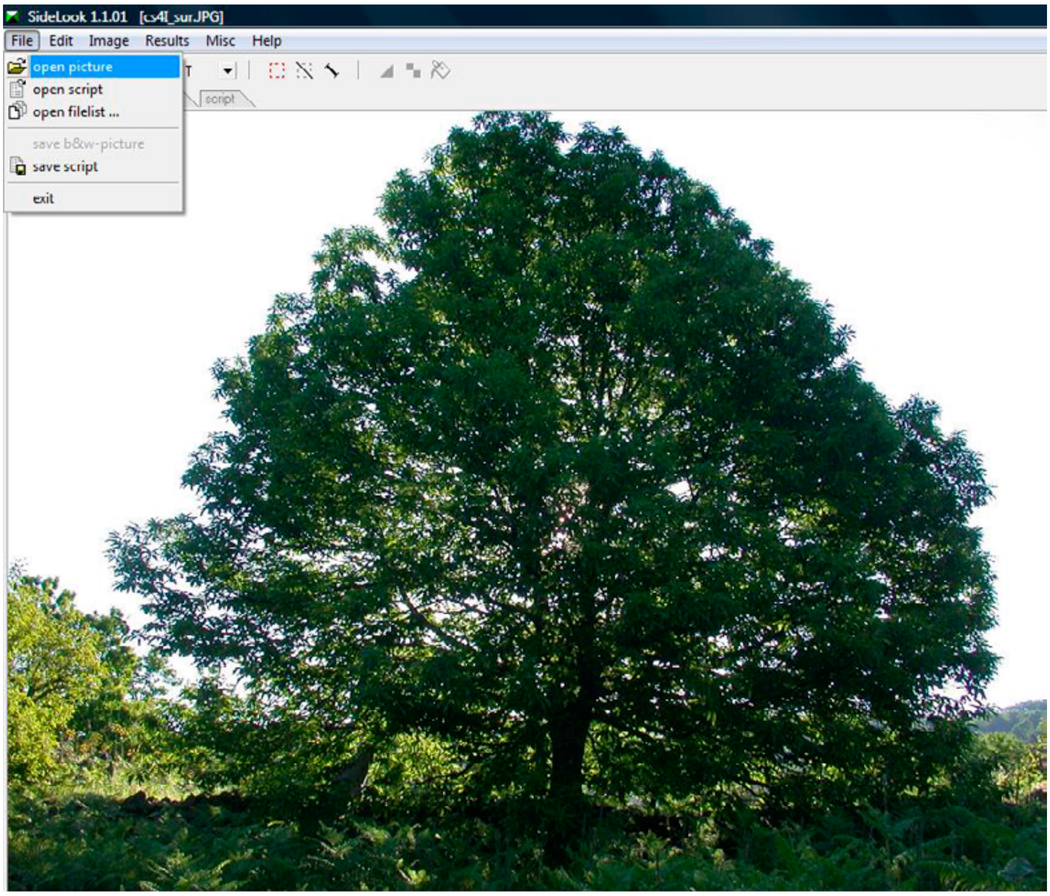


Figure 53. Vertical photo of a Form 4 sweet chestnut to be analyzed with Sidelook v.1.1. (Nobis & Hunziker 2005).

The next step is to turn the image into black and white. To do this in SideLook v.1.1., we activate *copy* and select *Threshold* from the *Image* menu (Figure 54). We are now in the window: *SIDELOOK-threshold-128.* Next with the left-hand mouse button we click on *blue*, then on *edge value* and finally we click on *Next* (Figure 54).

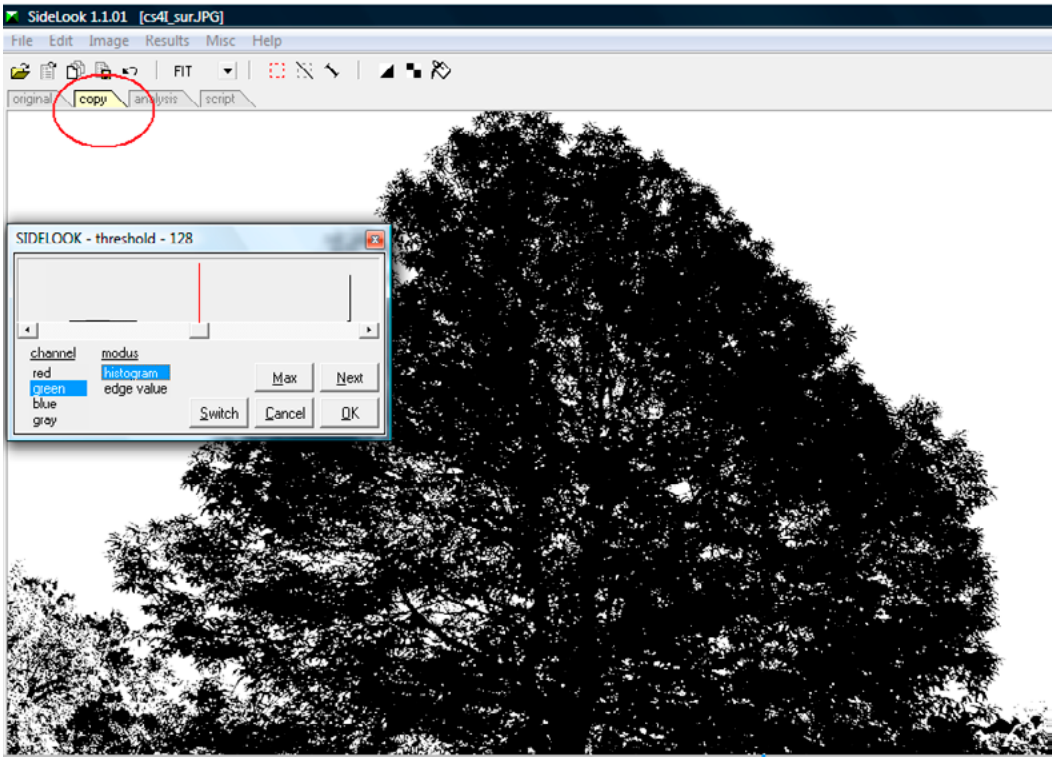


Figure 54. Vertical photo in black and white of a Form 4 sweet chestnut. The stage before obtaining the threshold with SideLook v.1.1. software.

Once this has been carried out, the window *SIDELOOK-threshold-182* appears on screen, in which can be seen the change of numbers from 128 to 182, and this is the threshold for changing the image to black and white in an objective way (Figure 55).

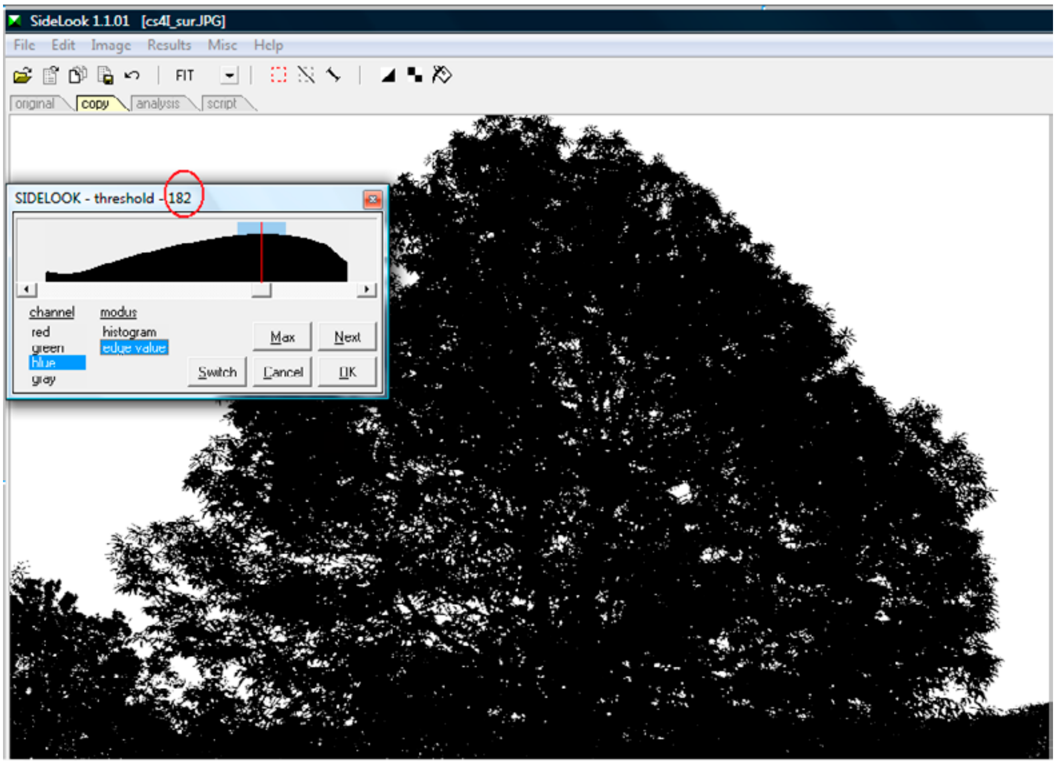


Figure 55. Vertical photo in black and white. Transformation threshold obtained with SideLook v.1.1. software.

Each photo gives a different threshold; therefore the process has to be repeated on all the photographic material.

ANNEX IV: ADOBE PHOTOSHOP CS5 ® SOFTWARE

ANNEX IV: ADOBE PHOTOSHOP CS5 ® SOFTWARE

The use of Adobe Photoshop CS5 ® software, which has been used in experiments I, II and III, of this thesis, is detailed below.

1. USE OF PHOTOSHOP IN EXPERIMENT I

Once the threshold for converting the photos to black and white has been obtained using SideLook v.1.1 Software.(previous Annex), the next step is to establish the zones of minimum filtering, edge filtering and average filtering on the tree canopy. To these ends, we select the tool *Lasso* on the pull-down menu to the left of the work window of the program, selecting on the tree canopy a zone which corresponds to one of the three filterings described above. In the *Histogram* window, where it says *Pixels,* we note down the total number of pixels found within the area selected (Figure 56).

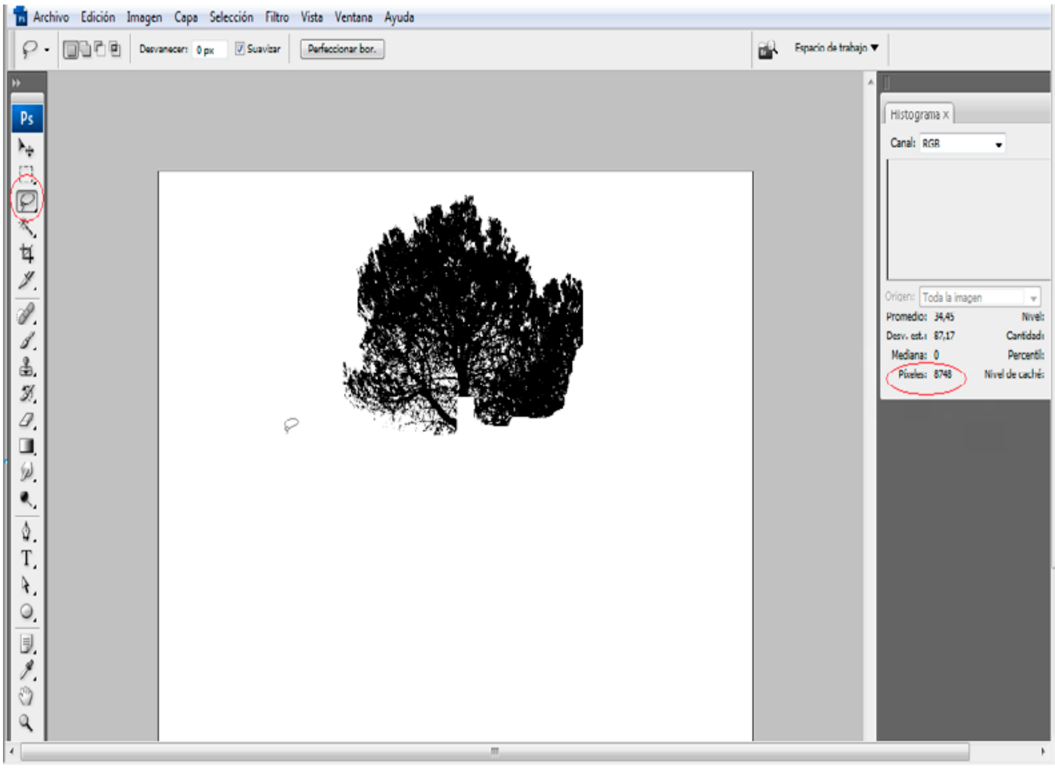


Figure 56. Vertical photo of a Form 2 pine tree in black and white. This is the stage in which the zones of minimum filtering, edge filtering and average filtering are established.

In order to distinguish the white pixels from the black pixels in the area, we will use the *Magic wand* tool, on the same pull down menu as the tool *Lasso,* subtracting the selection of white pixels. In the *Histogram* window*,* where it says *Pixels,* we note down the value of black pixels found within the selected area (Figure 57). This process is repeated until the three filtering zones have been obtained. The result will be extrapolated from the rest of the photo, weighing each zone of average filtering by the real total Surface in pixels that each class occupies in the canopy total, as explained in section 2.1.

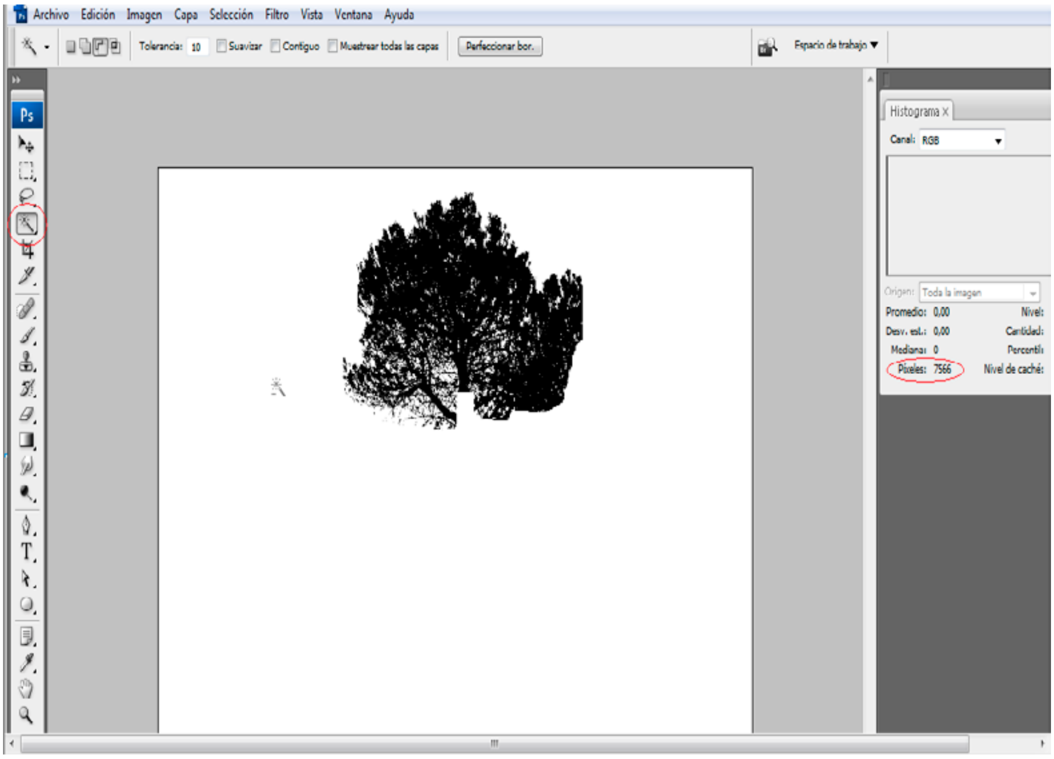


Figure 57. Vertical photo of a Form 2 pine tree in black and white. This is the stage in which the white pixels are subtracted from the selection made in the previous step. (Figure 4).

The next step is to extract from the total canopy the three zones that correspond to the three filterings (Figure 58). For this, we will use the same tools as in the previous stage and in the same way, except that this time we perform the selection on the total of the tree canopy. The values for the pixels are obtained the same way, in the *Histogram* window*,* where it says *Pixels,* we note down the total number of pixels in each filtering zone. Once this has been done, the selected zone is deleted using the *Del* button on the keyboard, so that other filtering areas are not selected.

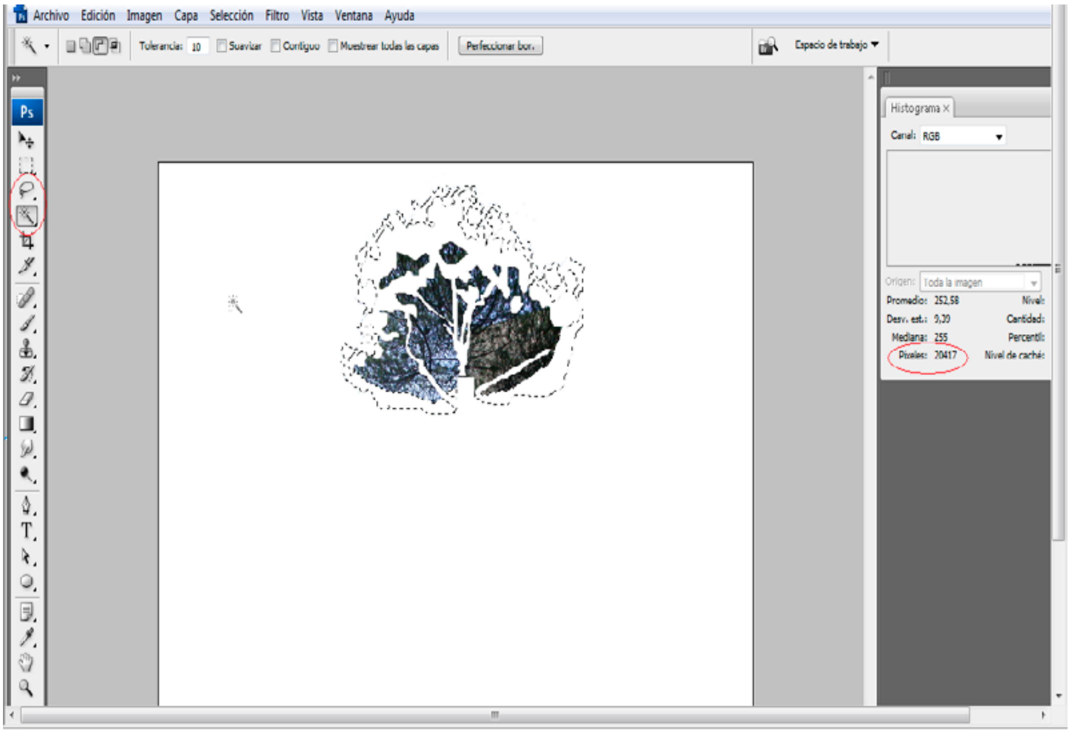


Figure 58. Vertical photo of a Form 2 pine tree with the zones of maximum filtering, edge filtering and medium filtering extracted

The analysis performed on the example photo must be repeated on all the photographic material and the results must be analyzed statistically as explained in section 2.1.

2. USE OF PHOTOSHOP TO CREATE VEGETATION SCREENS AROUND THE BUILDING

Although certain authors question the validity of the photographic method and express some doubts as to a photo representing a complex scene, bearing in mind the impossibility of assessing in the studio attributes which are imperceptible to the photo such as sound, smell and colour hues (Palmer & Hoffman, 2001), most studies vouch for the usefulness of this technique for landscape assessment (Shafer & Brush, 1977; Stewart *et al*., 1984; Hull & Stewart, 1992). Furthermore, infographic simulation from a photographed scene makes it possible to compare and rate distinct potential scenarios (Bishop & Leahy, 1989; Tress & Tress, 2003; Dockerty *et al*., 2006; García *et al*., 2006; Ghadirian & Bishop, 2008; Pinto-Correia *et al*., 2011; Barroso *et al.,* 2012).

As was explained in sections 2.2. and 2.3., Photoshop CS5 ® software was used to create infographs which would later be submitted to survey. This gave a total of 48 scenarios, 24 for each of the two experiments.

For experiment II, the infographs were modified by varying the height of the vegetation behind the building (Figure 59). This established the following height ratios:

1. The vegetation will not exceed the height of the gable of the building (Figure 59)
2. The vegetation will exceed the building height by 0% to 50% (Figure 59)
3. The vegetation will exceed the building height by 100% (Figure 59)

For experiment III, the infographs were modified by altering the filtering percentage produced by the vegetation on the building (Figure 60), in such a way that:

1. There is no vegetation in the infograph, producing 0% filtering. (Figure 60).
2. The vegetation gives filtering of up to 50% (Figure 60).
3. The vegetation causes a maximum filtering of 80% (Figure 60).

Figure 59. Mosaic of the 24 infographs created using Adobe Photoshop software.

Figure 60. Mosaic of images created using Adobe Photoshop CS5 ® software, in which the vegetation produces a filtering of 0% in the left-hand column, 50% in the middle column, and a maximum of 80% in the right-hand column.

ANNEX V: SKETCHUP 8 PRO © AND ARCGIS 10 ©

ANNEX V: SKETCHUP 8 PRO © AND ARCGIS 10 ©

As explained in experiment IV, we chose SketchUp 8 Pro © as modeling software and ArcGis 10 © as the plataform to visualize and establish the scenarios.

1. SKETCHUP 8 PRO ©

The google software SketchUp 8 Pro © was used to create the various 3D elements such as buildings and trees, taking photos of real trees and buildings as models. We used four photos per modeled tree to model them in 3D: one photo for each face or orientation of the tree, so that the modeling would be as accurate as possible in terms of tree geometry and structure (Figures 61 and 62). As with the creation of trees, the buildings found in the study area were used as models for the modeling of the buildings used in experiment IV, (Figure 63).

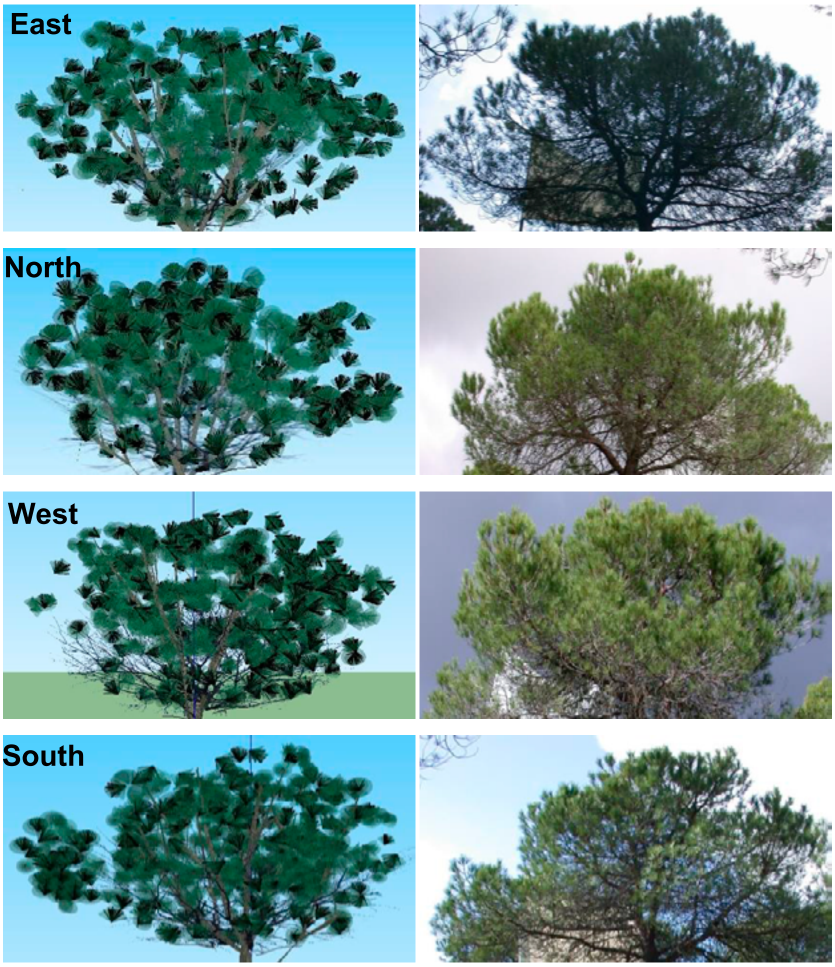


Figure 61. Creation of the canopy of a *Pinus pinea* in 3D, taking as model 4 photos of a real pine.

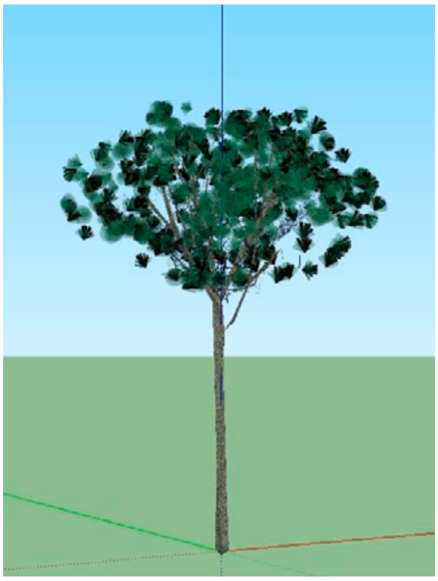


Figure 62. *Pinus pinea* modeled with SketchUp 8 Pro © software.

Figure 63. The left-hand column shows the building which uses the photos of a building in South Huelva study area as model (Experiment IV)

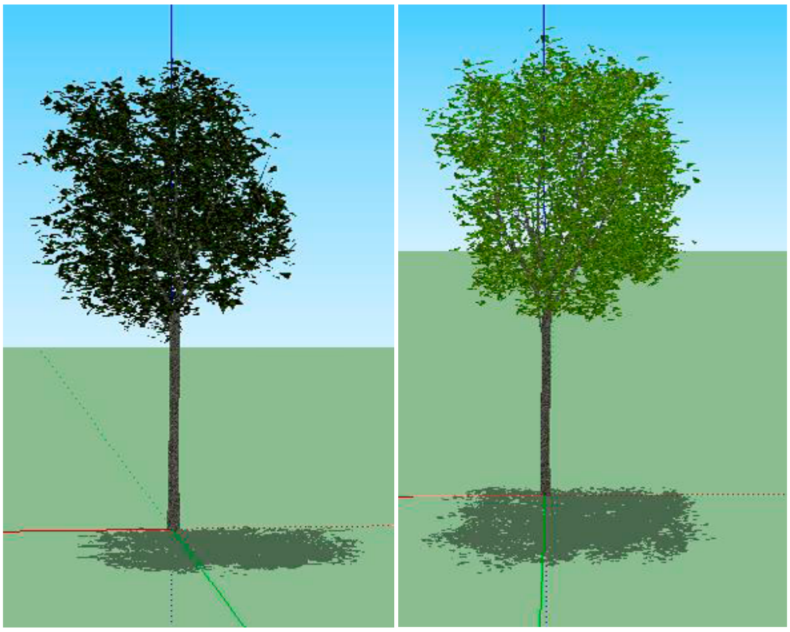


Figure 64. On the left the modeling of an oak, and on the right the modeling of a sweet chestnut. Both trees have been modeled using SketchUp 8 Pro © software.

The creation and modeling of 3D elements using SketchUp 8 Pro © was completed with the creation of two more tree species (oak and sweet chestnut) and their respective shadows (Figure 64). This allowed us to generate a greater realism to be used in ArcScene composition creation.

2. ARCGIS 10 ©

Once the modeling with SketchUp 8 Pro © software was completed, the next step was to prepare cartography pertaining to the two study zones chosen for experiment IV. For the scenarios of north Extremadura and south Huelva a digital terrain elevation model was established with a 25 m resolution and an orthophoto with 2.5 m resolution. The real virtual model of the sites under study consisted of an ortophoto with a 1 m resolution. The 3D objects like buildings and trees were located in the ArcScene of ArcGis 10 © module in the MDT which was constructed like a TIN (Figure 65). In order to obtain an accurate terrain representation, tracks and paths were edited by hand. The modelling and texturization of the 3D elements was based on data gathered in the field in the two study areas, as was explained in section 2.4.

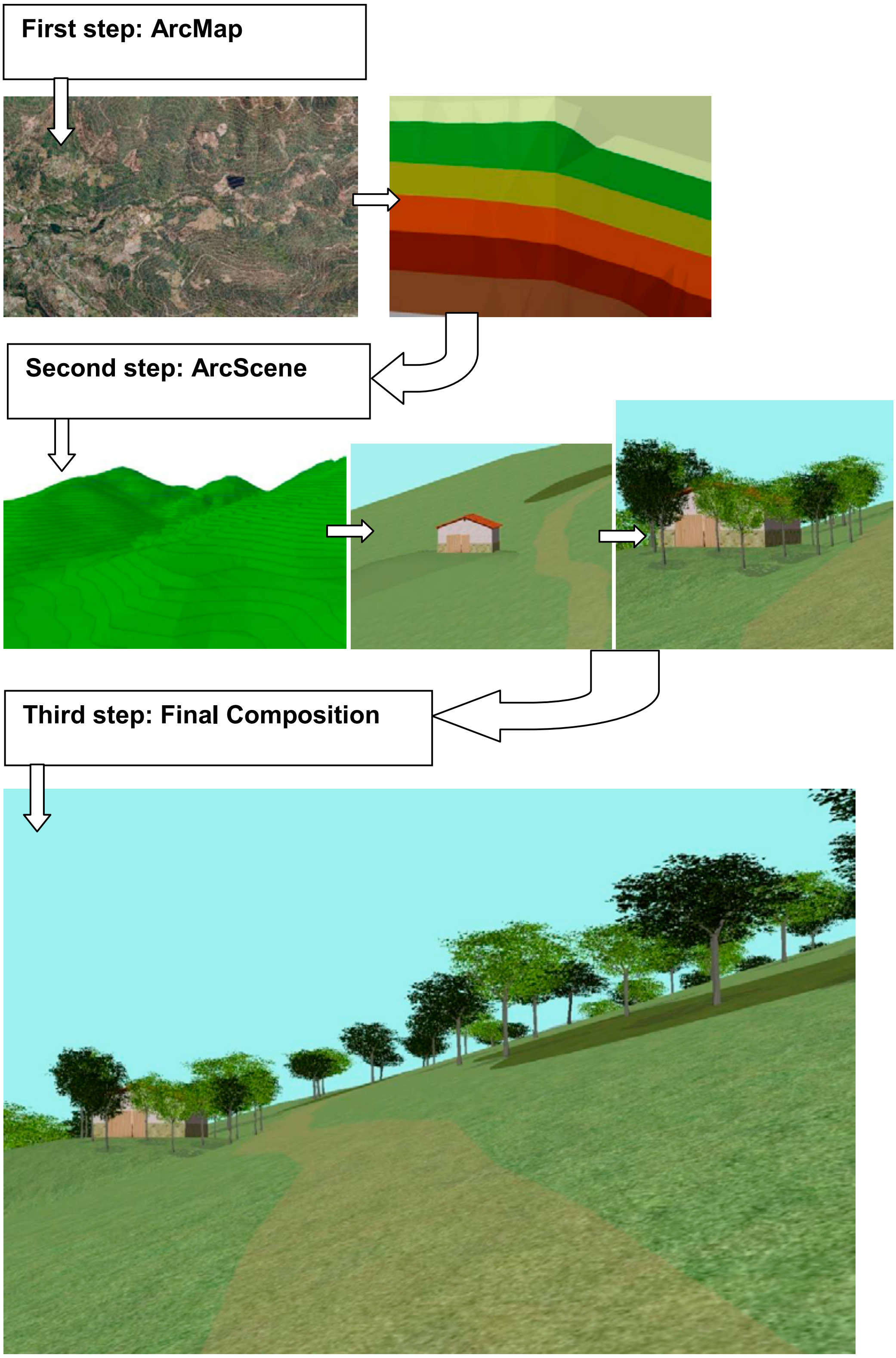


Figure 65. Graphic scheme depicting in a simplified way the 3-stage process of establishing, composing and visualizing the scenarios. Arcmap is used to generate the TIN from the contours and the orthophoto. The TIN created on Arcscene is loaded onto Arcscene and on it are laid the various elements which were designed using I SketchUp 8 Pro © software. The final composition shows us how the scenario for north Extremadura study area would be modeled.

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6.1. BIBLIOGRAPHY

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