

Restorative urban forests: exploring the relationships between forest stand structure, perceived restorativeness and benefits gained by visitors to coastal *Pinus pinea* forests

Abstract

Forests are widely recognized as important landscape elements which contribute to human health and well-being. They provide benefits derived from direct and indirect experiences of contact with nature by reducing psychological and physical stress, thus creating positive feelings and facilitating the recovery of psychological resources. In order to establish or manage forests for recreational purposes, it is essential to know which forest stand structure features and indicators are linked to actual or perceived psychological restoration. The aim of this study is to evaluate the association between individual factors, perceived restorativeness, stand structure attributes and self-reported physical-psychological benefits obtained when visiting woodlands in urban or peri-urban areas especially coastal Italian stone pine forests using a quantile regression approach. Perceived restorativeness components such as ‘being-away’, ‘fascination’ and ‘compatibility’ emerged as significant predictors of visitors’ perceived psychological benefits, showing a positive and significant association in all of the quantiles under study. Stand density, measured by basal area per hectare of understory trees and shrubs negatively influences the perception of the benefits obtained, holding constant the other covariates.

Keywords: Italian stone pine; pinewoods; quantile regression; physical and psychological benefits; Italy

1. Introduction

Natural environments in and around urban areas have provided people with valuable ecosystem services including the regulation of infiltration and storm water runoff, mitigation of the microclimate, reduction of the heat island effect and air pollution (De Groot et al., 2010; Dobbs et al., 2011; Larondelle and Haase, 2013). Furthermore, urban green infrastructures help to alleviate stress, enhance psychological and physical health and promote well-being in adults and children (Badiu et al., 2016; Hartig et al., 2010; Hauru et al., 2012; Tzoulas et al 2007). Many authors have reported that a natural environment is “restorative” when it promotes the recovery of psychological and physiological resources required by individuals to carry out daily life tasks, such as directed attention, self-control and other cognitive executive functions (see Hartig, 2004 for an overview). These benefits can be obtained by being in contact with nature (e.g. walking or cycling) or by simply viewing natural landscapes, e.g. from a hospital window (Ulrich, 1984).

In recent years, numerous studies have been carried out to investigate the relationships between overall individual well-being and various environmental dimensions, including climate, air quality, local amenities (Brereton et al., 2008; Ferreira et al., 2013; Rehdanz and Maddison, 2005; Wolch et al., 2014). Much attention has also been paid to comprehending how natural environments (e.g. trees, woodlands, community gardens) are related to the physical, psychological and social benefits obtained (Carrus et al., 2015b; 2017a; O’Brien, 2005; O’Brien and Morris, 2014) and the results showed that natural environments help to restore attention and reduce stress (Berman et al., 2008; Hartig and Kahn, 2016; Tennessen and Cimprich, 1995). Moreover, it has been determined that urban forest elements contribute to enhance human health and well-being better than built-up areas, particularly in densely inhabited areas (e.g., Carrus et al., 2013, 2015b; Van den Berg et al., 2007).

In this context, forests have been widely recognized as important landscape elements which positively affect human health and well-being (Arnberger and Mann, 2008; Hartig et al., 2003; Nordh et al., 2009; Petrokofsky et al., 2010) due to their relaxing qualities (Ottooson and Grahn, 2008). Direct and indirect contact with nature in urban forests help to induce positive emotions, reduce psychological stress and facilitate regeneration of cognitive resources (Nordström et al., 2015). This positive effect is even greater if woodlands are located within or adjacent to urban areas (Fuller et al., 2007; Miller, 2006; Peron et al., 2002). In this regard, Italian stone pine (*Pinus pinea* L.) forests located in Mediterranean coastal areas may be regarded as examples of urban and peri-urban forests which contribute to human well-being through a wide range of cultural services (Gasparella et al., 2017). Plantations of these species were originally established along the coasts of Mediterranean countries for mobile dune fixation and to protect crops against sea winds following wetland reclamation. However, due to the intensive urbanization process these forests have become important components of urban and peri-urban landscapes and have assumed different roles. In fact, nowadays most sites are renowned for their social functions such as scenic beauty and recreational use (SoMF, 2013; Gasparella et al., 2017) instead of being important for the production of pine nuts and timber. As a result, pinewoods are currently managed with the silvicultural system based on single-tree selection according to the principles of “urban forestry” (Randrup et al., 2005; Konijnendijk et al., 2006). Despite the amount of literature on the relationships between landscapes, perceived benefits and stress relief provided by natural environments, further research is still required. Much attention has been paid to evaluating the benefits provided by different green space typologies and changes in individual perceived restorativeness when exposed to different degrees of urbanization (Hauru et al, 2012). However, the effect of stand structure (i.e. the horizontal and vertical distribution of forest stand components including height, diameter,

crown layers of trees and shrubs) within the same forest type has not yet been explored. Furthermore, from a policy perspective, it is interesting to examine what occurs throughout the entire distribution of individual beneficial outcomes while visiting woodlands, instead of merely focusing on the conditional mean of distributions. More specifically, the benefits associated with forest trips can be assessed by directly asking visitors “in situ” to estimate the improvement in their subjective well-being and/or the benefits perceived at psychological or physical level during or following their experience. This is generally carried out by administering standardized questionnaires that have been subjected to conventional psychometric validation by previous empirical studies (e.g., Carrus et al., 2015a; 2017b; see also Mercado-Doménech et al., 2017, for a recent account of the basic psychological processes involved in human evaluation of external environmental stimuli and self-awareness of inner mental states). In fact, analyzing the entire empirical distributions could help policy makers and land managers to plan targeted and effective policies and management interventions aimed at enhancing individual benefits and well-being (Scopelliti et al., 2012). However, in order to establish or manage forests for stress relief, it is essential to determine which elements are required for creating restorative environments. When managing woodlands for recreational purposes it is important to take into account both the vertical (e.g., composition and density of overstory and understory) and the horizontal (e.g., spatial distribution of trees and stand density) structure of forests (Nielsen et al., 2012). For instance, tree size is an important variable for recreational value (Edwards et al., 2010) as well as the forest development phase (Edwards et al., 2012). Due to the increasing interest in using urban forests for promoting human health, it is also essential to understand how users perceive them as resources for obtaining benefits and enhancing well-being. Indeed, it is not feasible to propose effective management recommendations for cultural or landscape services without considering the users’ preferences (Nordström et al., 2015).

Bearing these considerations in mind, the aim of this study is to contribute to the literature regarding the cultural services provided by urban forests and how people perceive them. In particular, using Quantile Regression Models (QRMs) our aim is to determine the relationships between stand structure attributes, individual factors, perceived restorativeness, and the entire distribution of the physical and psychological benefits gained when visiting woodlands in urban or peri-urban areas. Three different examples of urban and peri-urban Italian stone pine forests located in the coastal areas of Latium were considered.

2. Theoretical framework and research hypotheses

People have always regarded contact with nature as an essential human need and green environments as indispensable for their health (Ward Thompson, 2011) and well-being. An important aspect of the psychological benefits and well-being obtained from being in contact with nature is the extent to which people perceive it as being restorative (e.g., Carrus et al., 2017a; Hansmann et al., 2007; Hartig, 2011; Laforzezza et al., 2009; Nordh et al., 2009). Even if perceived restorativeness, benefits and subjective well-being are associated, they are different constructs from both theoretical and empirical perspectives. Therefore, it is worth investigating the association between perceived restorativeness, psychological benefits and/or subjective well-being in different forest settings. According to Laforzezza et al. (2009), well-being can be defined as the combination of attributes leading to a mentally and physically comfortable psychological state. It is related to specific aspects including life satisfaction, sense of happiness and positive evaluation of one's life in general, but it can also be influenced by positive experiences such as visiting highly restorative environments that are capable of providing both psychological and physical benefits (e.g., Carrus et al., 2015b; Laforzezza et al., 2009).

In this paper, psychological benefits (PSBs) are deemed to be improvements in positive emotions, relaxation and subjective well-being which have a calming effect and reduce mental fatigue. On the other hand, physical benefits (PHBs) are defined as the advantages related to improvement in muscle strength, agility and posture, as well as to a range of mechanisms such as metabolism, respiration and circulation (e.g., Hartig, 2008; Laforteza et al., 2009). Various theories, such as the Attention Restoration Theory (ART) (Kaplan, 1995; Kaplan and Kaplan, 1989) and the Stress Reduction Theory (SRT) by Ulrich et al. (1991), have focused on the possible beneficial effects of being in contact with nature. While the ART mainly refers to the possible psychological benefits, the SRT concerns the possible physical benefits (see also Carrus et al., 2015a).

ART foresees that some environments (and related experiences) may aid the recovery of psychological resources that individuals use to carry out ordinary daily tasks, such as directed or voluntary attention (Kaplan & Kaplan, 1989). Direct attention is the ability to inhibit distractions during ordinary activities, which requires a cognitive capacity that can be depleted if subjected to severe and prolonged requests (Directed Attention Fatigue). Therefore, improved executive functioning may be acquired by being in contact with “restorative” settings, such as natural environments in which individuals can enjoy pleasant experiences without using an excessive amount of voluntary or direct attention (Berman et al., 2008; Hartig, 2004).

According to ART, restorative environments are characterized by four components or properties: (i) *being-away*, (ii) *extent*, (iii) *fascination*, and (iv) *compatibility* (Kaplan, 1995). *Being-away* refers to experiencing an environment physically different from one’s own usual environment in which direct attention is used. The *extent* concept is related to the physical features of an environment. It should be wide enough to capture the attention of people over time, thus promoting exploration without cognitive effort. *Fascination* refers to effortless

passive attention. Indeed, environments provide positive aesthetic stimuli thus promoting regenerative experiences. Lastly, *compatibility* is related to the ability of a place to be in line with the user's expectations and to support his/her engagement in environmental features or processes.

In general, environments with high levels of naturalness or biodiversity (versus settings with lower biodiversity levels) have all of these properties and are usually deemed to have a higher psychological restoration potential (Carrus et al., 2013; 2015b). Although several studies have reported on this issue (e.g., Hartig and Cooper Marcus, 2006; Sonntag-Öström et al., 2014, Velarde et al., 2007) and it has been explained by the Biophilia Hypothesis framework, there is still much controversy regarding the relationships between specific environmental characteristics (such as biodiversity richness or complexity of forest structure) and user preferences (or psychological restoration). In fact, in some cases no relationships have been observed (Qiu et al., 2013). Furthermore, natural settings may even induce negative feelings (Bixler and Floyd, 1997; Henwood and Pidgeon, 2001; Sreetheran and Konijnendijk van den Bosch, 2014) and users may show ambivalent attitudes towards urban green spaces (Bonnes et al., 2011; Carrus et al., 2004). This controversial issue suggests that in depth studies should be carried out on the relationship between the characteristics of natural settings and positive psychological or physical outcomes. In this framework, the aim of this study is to verify the following three research hypotheses:

RH1) The perceived restorativeness components are significantly associated with the PSB and PHB of individuals visiting pinewoods, even when stand structure variables are accounted for. In order to verify this hypothesis, we estimated two different specifications of QRMs: firstly, we estimated the model that only included individual variables and ART

components; we then estimated the full model to which forest stand structure variables were included.

RH2) Stand density is negatively associated with the perception of the benefits gained when visiting urban and peri-urban forests. In order to test this RH we determined the relationship between the density (basal area) of the trees and shrubs located in the understory layer and self-reported benefits.

RH3) Tree size is positively associated with self-reported benefits. In particular, we determined whether the mean diameter of trees in the overstory layer was associated with PSB and PHB.

3. Study area

The Italian stone pine forests under study are located along the coastline of the provinces of Rome and Viterbo (Central Italy) and belong to the European Forest Type 10.1 – Mediterranean pine forests (Barbati et al., 2014). In order to better evaluate the association between forest stand attributes and perceived benefits, we selected three coastal pinewoods with different forest stand structures (from even aged to composite structure) as case studies (Fig. 1).

(Here figure 1)

All of the three pinewoods (Montalto Marina, Fregene, Castelfusano) were established by sowing or planting. Montalto Marina pinewood is owned by the Civic Municipality of Montalto di Castro and extends across a total area of 17.94 ha. It is part of an extensive

reforestation program implemented by the National Forest Service, the Maremma Reclamation Consortium and some private land owners along the coast of the province of Viterbo from the 1930s to the 1960s. The forest is mainly used for tourism and/or recreational activities: there are numerous facilities such as benches, jogging trails, children's playgrounds and an altar for religious rites. A part of this pine forest is occupied by a campsite.

The pinewood in Fregene was established at the end of 19th century as part of a land reclamation program along the coast of Latium. The pine forest is located within the urban area of Fregene, it covers a total area of 31 ha and is crossed by main roads in several places. This pinewood is mainly used as a public park and contains benches, children's playgrounds and a dog-friendly walking trail. A shrub layer is present under the forest cover which is composed of termophilous evergreen broadleaves such as *Pistacia lentiscus* L., *Phyllirea* spp. and *Quercus ilex* L. Some pines have also recently been planted to replace dead trees and preserve the landscape.

Castelfusano pinewood is a large wooded area characterized by a high environmental, social and cultural value, located within the municipality of Rome. The first reforestation programs began in 1710 and continued with subsequent establishments in 1880, 1887, 1933. The pine forest is part of a large wooded area covering more than 1,100 ha (250 ha of pinewood) and has been part of the Natural Reserve of the "Litorale Romano" since 1995. This woodland is characterized by forest stands with different structures (Agrimi et al., 2005). Age and past forest management led to the formation of complex and multilayered structures, alternating with some bi-layered stands. There is also a dense and continuous shrub layer of evergreen species (*Pistacia lentiscus* L., *Erica arborea* L., *Arbutus unedo* L., *Myrtus communis* L., *Phyllirea* spp.).

4. Material and methods

4.1 Evaluation of the self-reported benefits

Self-reported PSB and PHB were evaluated by asking randomly recruited visitors to the three pinewoods under study to fill in a questionnaire divided into three sections. The first section included questions concerning the visitors' demographic data (e.g., gender, education, age). The second section focused on evaluating the perceived *restorativeness* of the studied settings, through the Perceived Restorativeness Scale (PRS), by Hartig et al. (1997). The PRS is the most widely known and used psychological tool to measure individual ratings of how much a specific setting is perceived as restorative by an individual, referring to the four main dimensions of ART: *being-away*, *extent*, *fascination*, *compatibility*. In our study, we used four items of the Hartig et al. (1997) original PRS (one for each of these dimensions; see Table 1) taken from an Italian version already subject to empirical assessment (Pasini et al., 2009). The third section focused on the evaluation of the psychological and physical benefits obtained by visiting the pinewood. The use of self-report items for assessing psychological and physical benefits is a frequent procedure in social and behavioral science, although this might be subject to methodological limitations. In particular, considering respondents self-reports of physical health may be confounded with psychological well-being. Thus, one shall also be aware of the possibility of an oversimplification of our physical benefits measure, especially when using QRM (Table 1).

(Here Table 1)

In accordance with literature (Lafortezza et al., 2009; Carrus et al., 2015b), we used a five-point numerical scale of measurement for the questions and statements included in the second and third sections in which the respondents were asked to indicate their degree of

disagreement/agreement, ranging from 1 to 5. The numerical score selected by each interviewee enabled us to measure both the direction and intensity of the responses. In fact, it is important to underline that all of the questions/statements were formulated in the same syntactic positive direction: as clarified to the participants, the higher the score assigned to the specific statement, the higher the level of agreement perceived. The use of only positive statements was justified by practical coding reasons, although it is important to be aware that this solution could give respondents less space to express negative or ambivalent feelings towards some natural spaces (e.g., high density forests; see also Bonnes et al., 2011).

218 individuals (52% women; mean age = 41.7 years; SD = 18.6 years; Table 2) were recruited in the study: 72 (33%) visited the pinewood in Montalto Marina, 69 (32%) visited the pinewood in Castelfusano and 77 (35%) visited the pinewood located in Fregene. Sample size was determined in accordance with similar comparative studies (e.g. Carrus et al., 2017b). The data were collected between May and early July 2014. The questionnaires were only completed during daytime (from 11 am to 6 pm) on sunny (or moderately cloudy) days, without rain. The participants were informed of the anonymous nature of the survey. In order to avoid confusion, the meaning of PSB and PHB was briefly explained to the respondents.

(Here Table 2)

As shown in Table 3, the PSB and PHB distributions of are negatively skewed, with mean values of 3.74 (SD=0.97) and 3.45 (SD=1.02), respectively. This evidence suggests the suitability of the QRM approach for analyzing the relationships between the perceived benefits, the selected variables regarding the restorativeness components and specific characteristics of urban forests, by using the respondents' socio-demographic characteristics as control factors.

(Here Table 3)

4.2 Stand structure variables

Due to their origins and management systems, Italian stone pine forests can be characterized by various stand structures: mono-layered; bi-layered or multi-layered forest stands (Fig. 2). If these forest types coexist in relatively small areas, the structure of the forest is described as "composite" (Agrimì et al., 2005; Zhu et al., 2003). Montalto and Fregene pinewoods are characterized by homogeneous stand structure (mono-layered and bi-layered, respectively) while multiple stands (bi-layered and multilayered) were found in Castelfusano.

(Here Figure 2)

The stand structure of the three study areas were evaluated by collecting dendrometric attributes within the 13m-radius sample plots (530 m²). 6, 8 and 12 randomly placed sample plots were surveyed in Montalto Marina, Fregene and Castelfusano pinewoods, respectively. Diameter at breast height (DBH) and total height were measured for all the trees with DBHs larger than 3 cm within the plots and total height was measured using an ultrasound ipsometer (Vertex). The key stand structural attributes describing the overstories and understories of the pinewoods under study are reported in Table 4. We are in accordance with Assmann (1970) who defined the understory as the layer representing 0-50% of the maximal height of the stand. In all plots, the overstories were only characterized by Italian stone pines while the understories were only composed of evergreen broadleaves (*Quercus ilex*, *Pistacia lentiscus*, *Erica arborea*, *Arbutus unedo*, *Phyllirea* spp.).

(Here table 4)

Since density indices proved to be highly correlated (the Pearson correlation coefficient was approximately equal to 0.9), the basal area was used to measure density of stand as it provides information on both the number of trees and their sizes. Therefore, a more comprehensive picture of stand structure was obtained.

4.3 Definition and specification of quantile regression models

In the framework of our research, QRMs can be useful tools for obtaining a complete picture of the relationships between environment and respondents' PSBs and PHBs perceived while visiting pinewoods. In fact, QRMs have recently been successfully applied in social studies concerning well-being and life satisfaction (Biggeri et al., 2013; Binder and Coad, 2011; Graham and Nikolova, 2015; Yuan and Golpewar, 2012). Similarly, by estimating slope parameters that vary at different quantiles of the conditional distributions of benefits, QRMs are also able to detect the differences across the various quantiles when studying the relationships between restorativeness components, stand structure variables and psychological/physical benefits obtained by individuals visiting natural environments. Conventional regression techniques, such as the Ordinary Least Squares (OLS), focusing on the conditional mean of the dependent variable give an incomplete picture of the relationship between the dependent variable and the covariates since "the very idea of OLS regressions is the averaging out of coefficient estimates over the conditional distribution of the dependent variable" (Binder and Coad, 2011). From a methodological perspective, QRMs specify the conditional quantile of the dependent variable y as a linear function of covariates (Koenker, 2005):

$$Q_{\theta}(y_i | \mathbf{x}_i) = \mathbf{x}_i' \boldsymbol{\beta}_{\theta} + \varepsilon_{i\theta} \quad (1)$$

where y_i ($i=1, \dots, n$) is the dependent variable – which is represented in our study by the PSB and PHB levels perceived when visiting pinewoods –, $\mathbf{x}_i$ is a sequence of k -vector of regressors, $\boldsymbol{\beta}_{\theta}$ is an unknown vector of regression parameters associated with the θ th quantile while $\varepsilon_{i\theta}$ is an unknown error term.

According to Koenker and Bassett (1978) who introduced QRMs, the θ -th regression quantile, $0 < \theta < 1$, is defined as any solution to the minimization of the sum of absolute deviation residuals:

$$\min_{\boldsymbol{\beta} \in R^k} \left\{ \sum_{i: y_i \geq \mathbf{x}_i' \boldsymbol{\beta}} \theta |y_i - \mathbf{x}_i' \boldsymbol{\beta}| + \sum_{i: y_i < \mathbf{x}_i' \boldsymbol{\beta}} (1 - \theta) |y_i - \mathbf{x}_i' \boldsymbol{\beta}| \right\} \quad (2)$$

which is solved using linear programming methods. When θ is continuously increased from 0 to 1, the entire conditional distribution of y conditional on x is obtained. QRMs can be viewed as a weighted regression: instead of dividing the sample into segments according to the specific values (range of values) of the dependent variable, QRMs assign different weights to data points depending on whether they are above or below the line of best fit (Binder and Coad 2011; Graham and Nikolova, 2015).

In order to identify the factors influencing PSB and PHB obtained by visiting pinewoods and considering equation (1), we specified and estimated two QRMs in which the dependent variable y_i ($i=1, \dots, n$) was assumed to be PSB for the first model and PHB for the second model. In both models, the k -dimensional vector $\mathbf{x}_i$ of covariates includes factors describing the restorativeness components defined according to the ART.

With the aim of testing the specified RHs, the models were estimated in two separate steps: firstly, we estimated models by only including the restorativeness components as covariates; in the second step, the basal area per hectare of Evergreen Broadleaved Species (G_EBS) and the mean diameter (Dg) of the dominant tree species were introduced in order to account for the stand structure peculiarities of each site. It is worth noting that we included the respondents' socio-demographic characteristics (age, gender, level of education) and the distance of the visited pinewood from the respondents' homes as control factors in both estimation steps. In particular, distance from home was included as it emerged as a potential meaningful factor in the perceived benefits of visiting urban forests (see Laforteza et al., 2009). To facilitate respondents, rather than asking for a continuous estimate, we provided them a fixed-choice question with three categories: <600 m; 601-2000 m; >2000m.

5. Results

The estimation results - reported for PSB and PHB in Figures 3 and 4, respectively - show the parameter estimates at quantiles 0.25, 0.5 and 0.75 for the QRM which include also the stand structure variables. The QRM estimates were carried out using STATA 13.0 software. It is worth noting that the estimation of the conditional density functions was obtained by using as estimator a function of the fitted values.

(Here figure 3)

(Here figure 4)

The restorativeness components proved to be good predictors of PSBs. In the model without stand structure variables (see Appendix A, Tables A1 and A2), *being-away*, *fascination*

showed a positive and significant association with all of the reported quantiles. Moreover, *compatibility* was significantly and positively associated with PSB at 0.5 and 0.75 quantiles. On the other hand, the area of pinewood and the coherence of its elements (*extent*) did not affect PSB.

The significance of the covariates changed when forest stand structure variables were included. Indeed, while the magnitude of coefficients did not vary notably in absolute terms, we observed variations in their significance levels: *extent* became significant at both 0.25 and 0.5 quantiles, while *being-away* was only significant for the participants experiencing the highest levels of PSB (i.e. at 0.75 quantile). Individual variables (gender, age, distance from visitor's home, level of education) were not significant in all of the quantiles.

Concerning PHBs, the restorativeness components did not appear to influence on the dependent variable at the 0.25 quantile, while their positive influence was observed at both 0.5 and 0.75 quantiles. Among the control variables, age proved to be strongly and positively associated with the physical benefits perceived in all of the quantiles under study.

We evaluated partial goodness of fit of the estimated models using the Pseudo R^2 index proposed by Koeneker and Machado (1999), which is the likelihood ratio of the sum of the weighted absolute distances for the full QRM estimated at the q^{th} quantile and the sum of the weighted absolute distances for the model which only included the intercept estimated at the same q^{th} quantile. The restorativeness components and the available control factors provided us with a moderate local fit of the models estimated for the lowest quantiles while the relative fit increased when explaining higher values ($q75$) of perceived benefits, with a better goodness of fit for PSB than PHB. Indeed, in QRMs the Pseudo- R^2 is a measure of relative effectiveness for a particular quantile rather than a global measure of goodness of fit across the entire conditional distribution (Chen and Chalhoub-Deville, 2014; Koeneker and Machado, 1999).

In order to provide valuable insights on the role forest stand attributes play in contributing to self-reported PSB and PHB, a graphical view of the QRM estimates is reported in Figures 5 and 6. The coefficient estimates of each stand variable (y axis) at different quantiles of the distribution of benefits (x axis) are reported in the graphs. Bootstrapped 95% confidence intervals are highlighted by grey-shaded areas.

(Here figure 5)

(Here figure 6)

The basal area of understory trees and shrubs (G_{EBS}) is negatively associated with the perceived benefits while holding constant the other covariates. In particular, a significant relationship was observed for PSB in most of its distribution: between the 0.15 and 0.75 quantiles. The significant negative relationship for PHBs was mainly located between the 0.5 and 0.8 quantiles.

The estimated coefficients concerning mean stem size of Italian stone pine (D_g) were very close to 0 were not significant for all the quantiles, although there were some fluctuations thus demonstrating that this variable was not directly associated with both PSB and PHB in our case study.

6. Discussion and concluding remarks

Much attention has recently been paid to the positive effects of natural environments on people's well-being since visiting green areas (including urban and peri-urban woodlands) increases both PSBs and PHBs (Carrus et al., 2015b; Nilsson et al., 2011; Sonntag-Öström et al., 2011) especially if woodlands are located in coastal areas (White et al., 2014). Our study

focused on Italian stone pine plantations whose ecological value varies greatly. Some long established pine plantations characterized by multi-layered stand structure with understory vegetation comparable to natural forest communities (*Quercetalia ilicis*) have become priority habitats under the EU Habitats Directive (2270 * Wooded dunes with *Pinus pinea* L. and/or *Pinus pinaster* Ait.). Our results - which can refer to most Mediterranean coastal pine forests under similar conditions – are in accordance with the results obtained from previous studies (e.g., Carrus et al., 2015b) which found that individuals benefit more from natural places in which they perceive higher levels of restorativeness components.

To the best of our knowledge, this is the first time that research determines if and to what extent the role of restorativeness components differs between perceived PSBs and PHBs while taking into account stand structure variables. *Being-away*, *fascination* and *compatibility* proved to be important predictors of PSB even when stand structure variables were taken into account and the socio-demographic characteristics of participants were used as control factors. This result is in line with our first RH and proves the association between the restorativeness components and perceived benefits also when stand structure variables are considered. Moreover, the restorativeness components were not significantly associated with the PHBs of the less satisfied individuals.

Edwards et al. (2012) and Swanwick (2009) demonstrated that landscape preferences can be influenced by a variety of human factors, such as age, gender, level of education, professional status, cultural background and recreational activity, as well as by differences between geographical regions. Our results suggest that in addition to environmental characteristics, which must be considered for explaining the benefits obtained, it might also be interesting to take into account individual attributes, as well as broader contextual characteristics (Judd et al., 2002).

Our methodological approach based on QRMs enabled us to evaluate the existence of association between the selected explanatory variables and the distributions of self-reported benefits at the various quantiles thus providing policy makers with valuable information for planning effective and targeted policies. In this perspective, the use of QRMs adds knowledge to the literature and provides additional information (for example by providing insights on the individuals with the lowest and the highest levels of perceived benefits) compared to conventional regression techniques, such as the OLS estimator.

The association between the two selected stand structure variables and PSB and PHB perception was also investigated. The value of the basal area of the plant species in the understories proved to negatively influence benefit perception, and this is in line with our second hypothesis (RH2). Dense and tall ground vegetation may cause a significant sight depth reduction which may induce negative feelings related to the perception of insecurity (Sreetheran and Konijnendijk van den Bosch, 2014) and may therefore reduce perception of benefits in our case study. Furthermore, other authors have suggested that vegetation density and visual penetration have a so-called "bell-shaped effect": the higher the increase in the density of the understorey layer, the more the level of recreational function increases up to a specific threshold after which the perception of positive feelings starts to decrease (Edwards et al., 2012). It is also worth noting that this result differed along the entire conditional PHB and PSB distributions. In fact, the association was significant for the central part of the PSB distribution and for the medium or high levels of individual PHB satisfaction. No significant association with this stand structure variable was observed for both the least and the most satisfied individuals, while it is likely that the most satisfied individuals received benefits from visiting forests regardless the stand structure.

Our findings suggest that relatively open forests characterized by tall mature pines with few understory shrubs are expected to have a stronger restorative effect than more "natural"

stands (uneven-aged stands with a structurally diverse understory). This stand structure helps to maintain an overview and provides a sense of open space, meaning that there is a trade-off between optimizing forest structure to provide psychological and physical benefits and improving stand structure in terms of age and size classes, stability and biodiversity. However, it is essential to consider stand structure and the related dynamics when managing forest areas for recreational purposes (Barbati et al., 2013; Marchetti et al., 2014). Silvicultural treatments in urban and peri-urban forest stands, considered to be complex ecosystems, should be planned following the criteria related to the above-mentioned concepts (Ciancio, 2011; Messier et al., 2016) in order to consider both natural stand dynamics and users' preferences. As stated by Braat and Brink (2008), management should not only focus on one environmental service, since it may result in a too intensive use of soil, which is not optimal for the long-term maintenance of all of the services. It may be advisable to select multifunctional management based on location, prevailing functions and the level of public use within the same forest stand and gradually reduce understory density around the main paths or other facilities, leaving the rest of the forest undisturbed. Structural differentiation can be an optimal strategy for increasing variability, diversity and landscape heterogeneity, in order to better adapt forest ecosystems to the effects of global change (Messier et al., 2013; Nocentini et al., 2017) and some plant and/or animal species may benefit from open forests. However, silvicultural treatments aimed at reducing understory density may reduce other ecosystem services and therefore should be very cautious. Furthermore, silvicultural cuts in urban and peri-urban forests may lead to a public backlash, so effective knowledge transfer and stakeholder engagement in the decision making process may help to reduce conflicts (Ugolini et al., 2015). Even if the stand density variable proved to be negatively related with the benefits perceived, unexpectedly the mean size of trees of the understory layer was not significantly associated

with both PSBs and PHBs, therefore the third hypothesis (RH3) was not verified. This result is in contrast with the findings of other authors, such as Edwards et al. (2012), who considered tree size to be the most important variable for defining the recreational value of woodlands yet people perceived positive feelings in our case studies regardless the size of the pines. This may be due to the cultural value of the pines considered in our study: in fact, Italian stone pines are regarded as landmarks by tourists and people residing around the Mediterranean basin (Gasparella et al., 2017) and the mere presence of this coniferous species might be sufficient for considering woodlands as restorative places. In fact, ecosystems are not only composed of physical attributes because they are influenced by cultural perceptions. The cultural values of certain sites or species may be important enough for local people so that they protect and conserve the ecosystems that contain them (Verschuuren, 2010). In this regard, further research is required in order to gain valuable insights on the effects that culturally-significant natural sites have on benefits perception. Our explorative results are a good starting point for carrying out further analyses in order to gain in-depth knowledge on the forest stand variables associated with individual benefits and well-being, as well as to identify additional individual characteristics explaining the PHBs and PSBs obtained when visiting urban forests thus leading to an increase of the explained variability. The effect of other stand structure variables on the benefits perceived - such as variability of tree size or mean height - can be taken into account by increasing the number of sites under study and referring to the multilevel statistical framework. Indeed, multilevel regression models would enable us to divide the overall variability into (at least) two levels: the first level concerns individual behavior while the second level is related to specific sites. As regards stand density, “number of trees per hectare” may be a relevant parameter to include in further studies and it may provide further information for forest management besides those related to basal area. Moreover, further studies should be carried out in order to

investigate other forest types (e.g., holm oak forests in the Mediterranean context) within or adjacent to urban areas. Forest size can be considered in order to evaluate if and to what extent users' perception differ when visiting small or large forests which may be useful for effective multifunctional forest planning as well as for green infrastructure designing. Using statistical methods which can analyze the entire distribution may provide valuable insight into the existing relationships between site characteristics and perceived benefits. In fact, understanding what occurs at the extremes of the distribution can be useful when designing effective interventions that far exceed the needs of the average individual. Lastly, our results referred to a cross-sectional survey therefore only association measures between variables were achieved. Future research should focus on longitudinal surveys in order to identify causal relationships between the various kinds of factors (ART components, socio-economic characteristics) and self-reported benefits when individuals come into contact with natural environments such as urban and peri-urban woodlands. Another limitation may concern the limited number of positively worded items used for measuring perceived restorativeness which may have generated a biased response set, even if previous empirical findings have suggested that valid and reliable assessments of perceived restorativeness can be achieved using shorter versions of the original Hartig et al. (1997) PRS scale (e.g., Berto, 2005; Negrin et al., 2017). Therefore, different measures and different research designs could help to increase the goodness of fit of the estimated models. As regards PHBs, although our models have a moderate fit, to the best of our knowledge, this is one of the first empirical studies which considers both the ART components and stand structure variables using QRM. Finally, interesting possibilities for novel research in this field (e.g., Lymeus et al., 2017; Panno et al., 2017) focused on the interplays between mental and cultural factors involved in human reactions to natural settings and environmental phenomena are required.

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Conflict of interest statement

None declared.

QRM_I (restorativeness components)					QRM_II (restorativeness components and stand structure variables)		
					coeff.	s.e.	sign.
					coeff.	s.e.	sign.
Q25	Restorativeness						
	Being-away	0.320	0.134	0.018	0.239	0.130	0.068
	Extent	0.140	0.090	0.121	0.202	0.086	0.019
	Fascination	0.284	0.121	0.020	0.375	0.124	0.003
	Compatibility	0.172	0.088	0.051	0.146	0.107	0.174
	Distance						
	Distance <600 m	ref			ref		
	Distance 601- 2000 m	0.598	0.330	0.072	0.127	0.373	0.733
	Distance >2000m	0.068	0.254	0.788	-0.129	0.313	0.681
	Socio-demographic characteristics						
	Gender (ref female)	-0.085	0.148	0.566	-0.179	0.156	0.253
	Age	0.007	0.005	0.180	0.004	0.005	0.384
	Education: Phd/universit y degree)	ref			ref		
	Education: high school	-0.250	0.204	0.222	-0.170	0.243	0.486
	Education: primary- middle school	-0.113	0.302	0.708	-0.316	0.290	0.278
	Stand structure variables						
	G_EBS				-0.097	0.044	0.028
	D _g				0.005	0.009	0.564
Q50	Restorativeness						
	being-away	0.211	0.095	0.028	0.162	0.094	0.088
	extent	0.111	0.064	0.082	0.112	0.056	0.046
	fascination	0.332	0.094	0.000	0.402	0.089	0.000
	compatibility	0.181	0.074	0.015	0.177	0.073	0.016
	Distance						
	distance <600 m	ref			ref		
	distance 601- 2000 m	0.228	0.219	0.299	0.329	0.215	0.127
	distance >2000m	-0.057	0.152	0.707	0.073	0.166	0.660
	Socio-demographic characteristics						
	gender (ref female)	-0.109	0.121	0.370	-0.112	0.121	0.354
	age	0.006	0.004	0.850	0.003	0.003	0.396
	Education: Phd/universit y degree	ref			ref		
	Education: high school	-0.139	0.147	0.343	-0.052	0.173	0.763
	Education: primary-	-0.013	0.200	0.949	0.027	0.195	0.888

	middle school						
	Stand structure variables						
	G_EBS				-0.094	0.036	0.011
	D _g				0.003	0.007	0.715
Q75	Restorativeness						
	being-away	0.258	0.116	0.028	0.216	0.102	0.035
	extent	0.073	0.067	0.275	0.068	0.068	0.318
	fascination	0.251	0.085	0.004	0.229	0.111	0.041
	compatibility	0.194	0.086	0.026	0.175	0.087	0.044
	Distance						
	distance <600 m	ref			ref		
	distance 601-2000 m	0.246	0.252	0.330	0.339	0.273	0.216
	distance >2000m	-0.046	0.196	0.816	0.071	0.226	0.756
	Socio-demographic characteristics						
	gender (ref female)	-0.097	0.184	0.598	-0.027	0.139	0.849
	age	0.002	0.004	0.663	0.005	0.004	0.214
	Education: Phd/university degree	ref			ref		
	Education: high school	-0.097	0.142	0.496	-0.059	0.155	0.702
	Education: primary-middle school	-0.058	0.161	0.720	-0.043	0.193	0.825
	Stand structure variables						
	G_EBS				-0.115	0.049	0.020
	D _g				0.004	0.009	0.624

Notes: Significant coefficients at $p < 0.05$ are reported in bold; Goodness of fit: *QRM_I*: Q25: Pseudo $R^2=0.1924$; Q50: Pseudo $R^2=0.2045$; Q75: Pseudo $R^2=0.2397$; *QRM_II*: Q25: Pseudo $R^2=0.2144$; Q50: Pseudo $R^2=0.2238$; Q75: Pseudo $R^2=0.2603$

561 Table A2. QRM estimation results: perceived PHB
562

QRM_I (restorativeness components)					QRM_II (restorativeness components and stand structure variables)		
coeff. s.e. sign.					coeff. s.e. sign.		
Q25	Restorativeness						
	being-away	0.118	0.147	0.423	0.115	0.160	0.472
	extent	0.096	0.111	0.392	0.084	0.107	0.433
	fascination	0.326	0.206	0.115	0.281	0.182	0.124
	compatibility	0.202	0.163	0.218	0.291	0.156	0.065
	Distance						
	distance <600 m	ref			ref		
	distance 601-2000 m	0.087	0.484	0.858	0.361	0.546	0.509
	distance >2000m	-0.208	0.390	0.593	-0.096	0.433	0.825
	Socio-demographic characteristics						
	gender (ref female)	0.292	0.207	0.160	0.250	0.241	0.300
	age	0.015	0.006	0.010	0.013	0.007	0.045
	Education: Phd/university degree	ref			ref		
	Education: high school	-0.241	0.247	0.332	-0.303	0.286	0.291
	Education: primary-middle school	-0.760	0.314	0.016	-0.556	0.361	0.125
Stand structure variables							
G_EBS				-0.078	0.064	0.225	
D _g				0.002	0.013	0.866	
Q50	Restorativeness						
	being-away	0.154	0.115	0.181	0.218	0.092	0.019
	extent	0.161	0.083	0.054	0.158	0.072	0.028
	fascination	0.234	0.113	0.039	0.268	0.107	0.013
	compatibility	0.192	0.098	0.052	0.114	0.094	0.226
	Distance						
	distance <600 m	ref			ref		
	distance 601-2000 m	-0.043	0.265	0.870	-0.072	0.321	0.824
	distance >2000m	-0.382	0.217	0.079	-0.378	0.251	0.134
	Socio-demographic characteristics						
	gender (ref female)	0.228	0.163	0.164	0.182	0.148	0.221
	age	0.016	0.005	0.001	0.015	0.005	0.001
	Education: Phd/university degree	ref			ref		
	Education: high school	-0.500	0.155	0.002	-0.491	0.200	0.015
	Education: primary-middle school	-0.377	0.298	0.207	-0.454	0.302	0.134

	Stand structure variables						
	G_EBS				-0.079	0.047	0.094
	D _g				0.001	0.007	0.855
Q75	Restorativeness						
	being-away	0.232	0.081	0.005	0.222	0.072	0.002
	extent	0.081	0.069	0.245	0.087	0.063	0.172
	fascination	0.242	0.085	0.005	0.171	0.065	0.009
	compatibility	0.051	0.066	0.447	0.126	0.063	0.047
	Distance						
	distance <600 m	ref			ref		
	distance 601-2000 m	-0.131	0.297	0.659	-0.080	0.226	0.723
	distance >2000m	-0.364	0.230	0.115	-0.369	0.215	0.087
	Socio-demographic characteristics						
	gender (ref female)	0.273	0.150	0.070	0.241	0.127	0.059
	age	0.010	0.004	0.020	0.012	0.004	0.003
	Education: Phd/university degree	ref			ref		
	Education: high school	-0.263	0.120	0.030	-0.352	0.133	0.009
	Education: primary-middle school	-0.192	0.218	0.380	-0.216	0.175	0.220
	Stand structure variables						
	G_EBS				-0.099	0.044	0.027
	D _g				-0.001	0.007	0.982

Notes: Significant coefficients at $p < 0.05$ are reported in bold; Goodness of fit: *QRM_I*: Q25: Pseudo $R^2=0.1211$; Q50: Pseudo $R^2=0.1911$; Q75: Pseudo $R^2=0.1282$; *QRM_II*: Q25: Pseudo $R^2: 0.1312$; Q50: Pseudo $R^2=0.2119$; Q75: Pseudo $R^2=0.1636$

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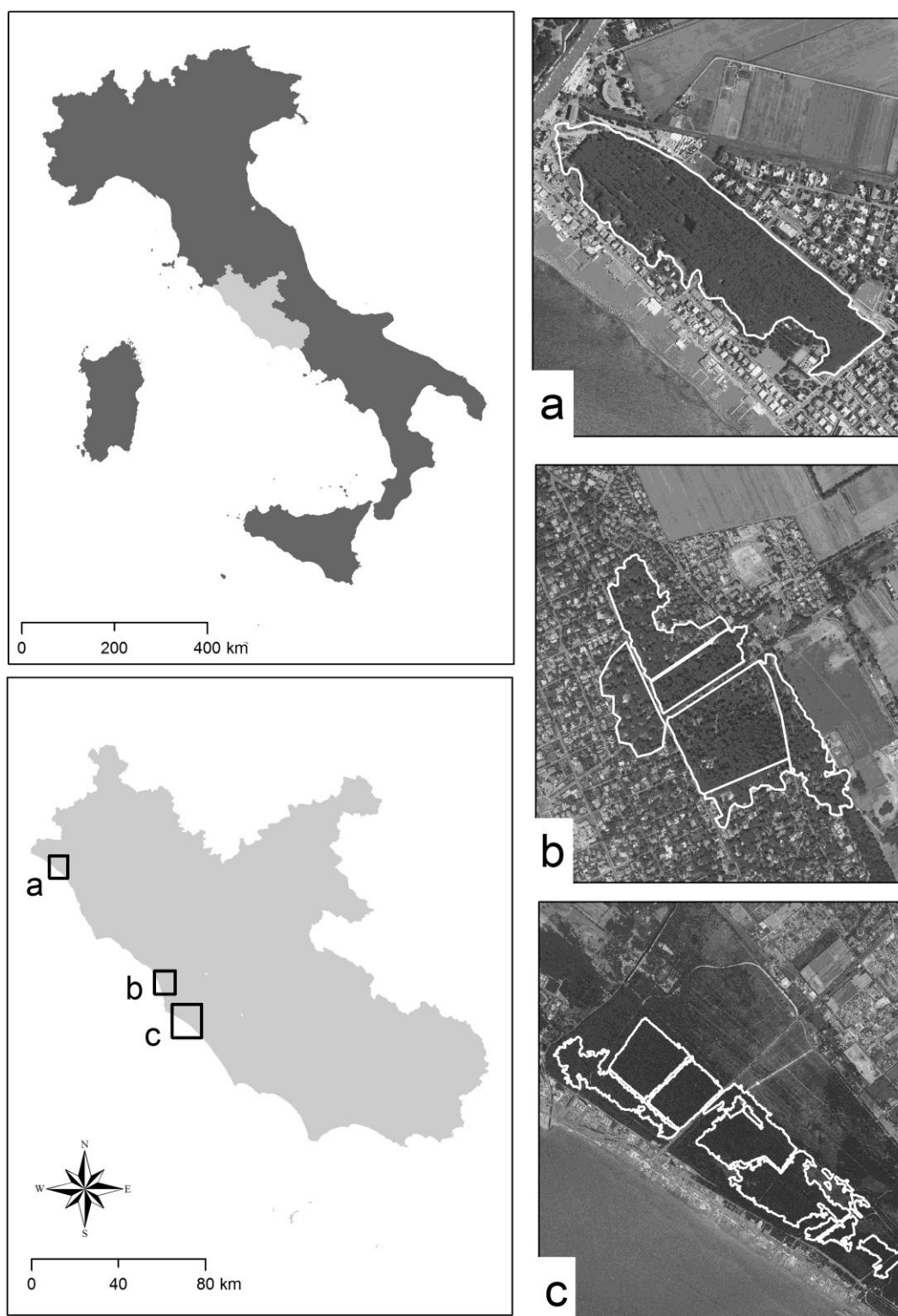
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821 **Fig. 1** Location of study areas along coastline of Latium region.



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823 **Fig. 2** Pictures of the three studied pinewoods.



Fig. 3 QRM estimation results for perceived PSB. Bars indicate estimated coefficients and standard errors. The reference for distances is “distance <600 m”, the reference for gender is “female” and the reference for education is “Phd/university degree”. Level of significance: * significant coefficient at $p < 0.05$; ** significant coefficient at $p < 0.01$.

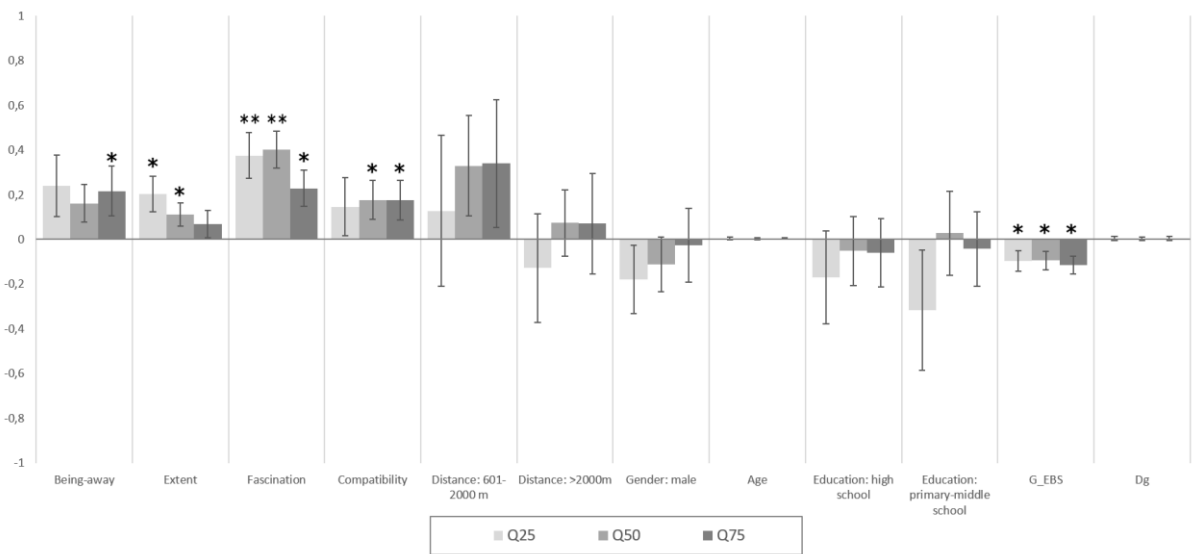


Fig. 4 QRM estimation results for perceived PHB. Bars indicate estimated coefficients and standard errors. The reference for distances is “distance <600 m”, the reference for gender is “female” and the reference for education is “Phd/university degree”. Level of significance: * significant coefficient at $p < 0.05$; ** significant coefficient at $p < 0.01$

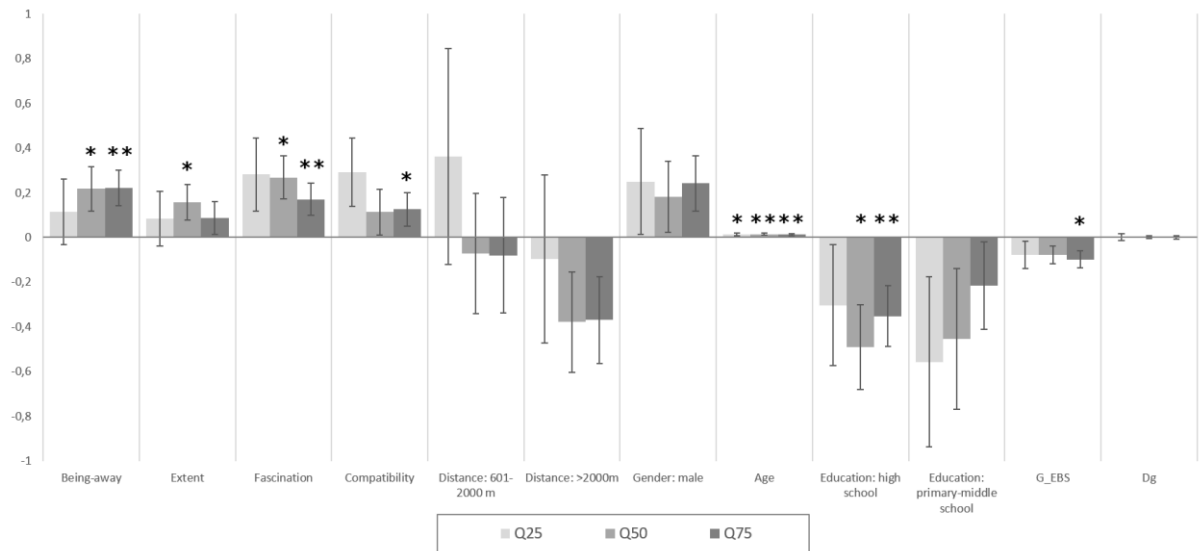


Fig. 5 Bootstrap 95% confidence interval (grey-shaded area) of quantile regression estimates for psychological benefits for D_g (left) and G_EBS (right).

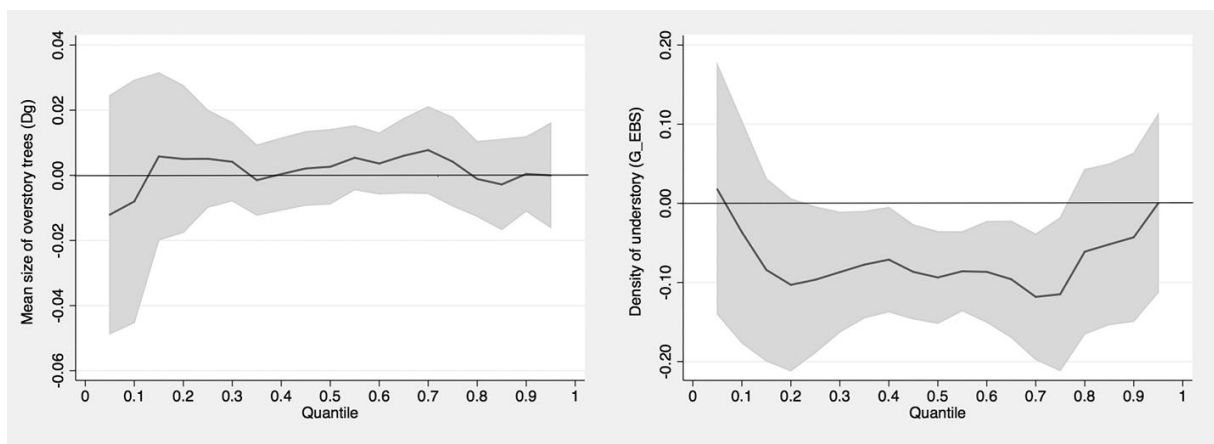


Fig. 6 Bootstrap 95% confidence interval (grey-shaded area) of quantile regression estimates for physical benefits for D_g (left) and G_EBS (right).

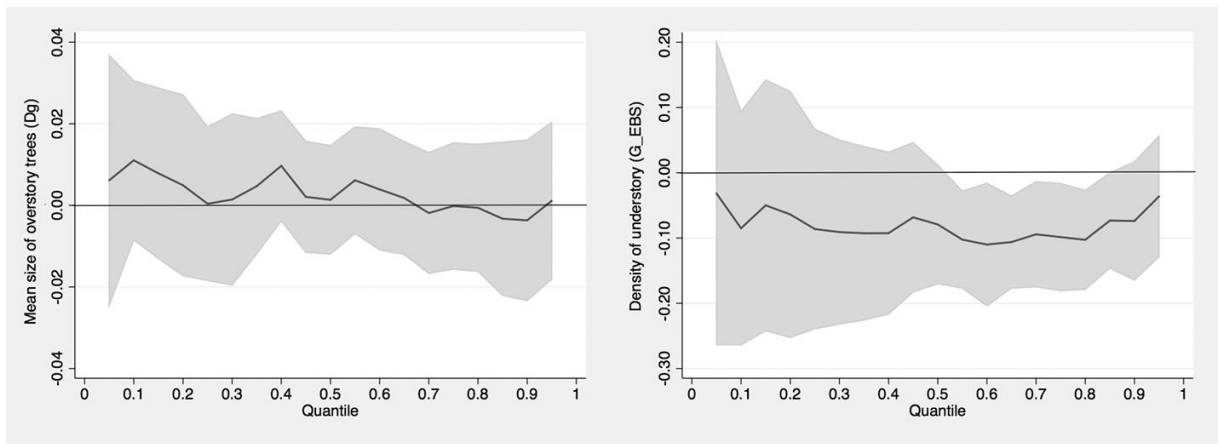


Table 1. Items used in this study to evaluate the perceived restorativeness and the psychological and physical benefits from pine forest visits

VARIABLE	Item
COMPATIBILITY	Being in this place is in accordance with my personal interests
BEING AWAY	Spending the time here allows me to distance myself from my daily routine
FASCINATION	This place is fascinating
EXTENT	It's like this place had no boundaries
PSYCHOLOGICAL BENEFITS	Do you feel psychological benefits during the visit to this place?
PHYSICAL BENEFITS	Do you feel physical benefits during the visit to this place?

850 Table 2. Main socio-demographic characteristics of the sample of respondents

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Socio-demographic characteristics	%
Gender	
Women	51.8
Age	
≤24	23.8
25-34	19.3
35-44	15.6
45-54	14.7
55-64	10.5
≥65	16.1
Level of education	
Primary-middle school	23.4
Secondary school	54.6
university degree/PhD	22.0

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855 Table 3. Descriptive statistics of psychological and physical benefits perceived while visiting
856 studied pinewoods.

variable	mean	median	min	max	skewness	sd	cv
Psychological benefits (PSB)	3.74	4	1	5	-0.58	0.97	0.26
Physical benefits (PHB)	3.46	4	1	5	-0.42	1.03	0.30

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858 Table 4. Main structural attributes of the two main layers of the studied pinewoods

		Castelfusano		Fregene		Montalto Marina	
		mean	SD	mean	SD	mean	SD
Overstory	Number of trees per hectare of Italian stone pine (N/ha)	157.2	77.3	125.0	26.6	270.7	59.6
	Basal area per hectare of Italian stone pine (m ² /ha)	31.8	8.4	38.2	9.7	28.3	5.5
	Mean diameter of Italian stone pine (cm)	54.6	14.9	62.4	7.9	36.8	4.9
Understory	Number of trees per hectare of evergreen broadleaved species (N/ha)	408.8	248.0	146.2	185.6	0.0	0.0
	Basal area per hectare of evergreen broadleaved species (m ² /ha)	5.1	4.8	2.5	2.7	0.0	0.0
	Mean diameter of evergreen broadleaved species (cm)	11.3	4.0	12.9	9.2	0.0	0.0

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