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Original article

The cultural landscape of Sintra, a UNESCO World Heritage Site—The balance between forest restoration and carbon stock

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ABSTRACT

Sintra's Cultural Landscape is a World Heritage Site and was the first cultural landscape to be listed in Europe by UNESCO, in 1995. It is a privileged ecosystem with natural and cultural value classified as priorities for conservation. Parques de Sintra-Monte da Lua is a state-owned company established to restore, maintain and promote the public properties in the World Heritage Site. The forest assumes an important role in Sintra's Cultural Landscape with the gradual removal of undesirable species and their replacement with multiple native tree species as one of the goals of forest management. Two aspects should be considered by the forest manager: opposing public opinion in terms of cutting dominant trees, most of the time linked with childhood memories and feelings, and its impact on the ecosystem's carbon stock. Removal and replacement of trees is part of the management of cultural landscapes and concerns like carbon stock and biomass losses cannot be priorities of the forest manager. This work evaluates the carbon stock balance obtained in a 20 ha forest by the removal of undesirable tree species and their replacement by native species. Twenty six inventory plots were measured and carbon stock was estimated to define the baseline of the study. Age-independent individual tree diameter equations, species specific height-diameter equations, and biomass allometric tree equations were used to estimate carbon in a 30-year horizon. Three management scenarios were considered. The results show that, after 30 years, the contribution of the native species to the carbon stock is small compared with the baseline carbon values, compensating only 30% of the carbon losses associated to forest restoration. Conflict management in a context of Cultural Landscape Forest is discussed.

1. Introduction

Cultural landscapes are those where human interaction with natural systems has, over a long time, formed a distinctive landscape (Mitchell et al., 2009). Sintra's Cultural Landscape is World Heritage (http://whc.unesco.org/en/list/723) and was the first cultural landscape to be listed in Europe by UNESCO in 1995. It is integrated into the Sintra-Cascais Natural Park and the Natura 2000 Network (PTCON0008), and is a privileged ecosystem with natural and cultural value classified as priorities for conservation. Parques de Sintra-Monte da Lua (PSML) is a state-owned company established to restore, maintain and promote the public properties in the World Heritage Site of Sintra. Nowadays, parks and monuments under the auspices of PSML attract around 1.5 million visitors per year, corresponding to 88% of the total number of tourists visiting cultural and natural sites in the Sintra Municipality every year.

Forests are complex ecosystems that provide a wide range of value to humans and play a multifunctional role in cultural landscapes that contribute to conserving native biodiversity (Mitchell et al., 2009; Roloff, 2016). Regarding the forest area, the main objectives of PSML are to recover the natural forest, to control the dissemination of invasive species, to reduce the sensitivity of the vegetation to fire as well as the potential risk of fire, to increase the landscape value and to improve the conditions that allow for increasing the number of visitors and the use of the site by the local community. The cultural and ecological sensitivity of visitors to sustainable management of the forest is also among the objectives of the PSML. In this context, the importance of forest tree species as a tool to mitigate CO_2 is explained to the visitors and to the local community, reinforcing the importance of the forest to the reduction of greenhouse gases (GHG) (e.g., Escobedo et al., 2010).

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PSML currently manages approximately 550 ha of forest. This forest is made up of native species and more than 200 exotic species that were introduced intensively in the 19th century, mainly for ornamental purposes. One of them, *Acacia melanoxylon* R. Br., became invasive, and its invasive behavior became more evident after the fires of 1966. This species spread over new areas, often associated with the occurrence of fire, reducing the biodiversity of the ecosystems in which it operates, often leading to inhibition of the germination of native species and also contributing to an increased risk of fire. The gradual removal of undesirable forest species, including invasive species, and their substitution by native forest species is one of the goals of management. Conversion to native broadleaved forests or to mixed forests with a higher prevalence of native tree species increases biodiversity, enhances the aesthetic value and improves biotic and abiotic resilience (Moreira et al., 2012; Roloff, 2016). However, forests with many small trees and few large trees are generally considered to be less appealing than old growth forests where there is a preponderance of large trees; some of these trees may even have a spiritual value (Sands, 2005). In many cases, a relatively minor modification of a planned management activity or the choice of the most appropriate technique to implement a silvicultural intervention as set out in the management plan may be necessary or enough to maintain the landscape visual appeal (Reed and Mroz, 1997; Auch et al., 2016). Forest managers should be able to explain to visitors and the local community that the harvest of undesirable trees, some of them visually dominant, despite changing landscape aesthetics and resulting in a reduction in the carbon stock (Nowak et al., 2002), is essential to break the production of new seeds and to promote the growth of native species. And some of the lost carbon can be offset by these new trees because, through growth processes, trees remove atmospheric CO_2 and store carbon within their biomass.

In this work, the impact of three management scenarios regarding the carbon stock and the dimension of stand trees is analyzed in a 30-year horizon. The carbon removed by harvesting the invasive acacia trees and two other species traditionally associated with production systems in Portugal (eucalyptus and maritime pine trees), as well as the carbon stock associated with the native species planted to substitute the harvested trees is estimated. The estimation is based on a forest inventory that took place in spring 2011, after the harvest of most of the acacia trees but before the plantation of native tree species that occurred in autumn 2011. The results of this study are the basis for information that is provided to the visitors and local inhabitants in order to support the acceptance of the forest management activities that are taking place. Also, findings from this study can be used as indicators for the establishment of integrated management plans of native forests in urban contexts and, particularly, in cultural landscape context.

2. Methods

According to the LULUFC (Land Use, Land-Use Change and Forestry) guidelines (IPCC, 2003) the stock-change method was chosen and the emissions/removals of carbon were evaluated by the difference between the carbon stocks in two successive inventories. In this work, the baseline was obtained by forest inventory used to characterize the forest in spring 2011. In the absence of the second inventory, we used estimates obtained with tree growth models and prediction equations available for the different forest species present in the study area.

2.1. Study area

Serra de Sintra has a Mediterranean climate with an Atlantic influence, with a relatively small annual temperature range (average 19 °C in the warmest month and 10 °C in the coldest month) and a high degree of humidity (INMG, 1991) that arises from the relative proximity to the Atlantic Ocean, the orography and the altitude of the mountain. The condensation of maritime air, favored by tree cover on the mountain, promotes the occurrence of precipitation (860 mm as mean annual value) (INMG, 1991) and fog (Moniz, 2004). Serra de Sintra is presented as the main geological feature of the Lisbon region with a maximum altitude of 528 m. Sintra's Eruptive Massif, of magmatic origin, is formed by eruptive rocks as the most common granite rock (Ribeiro et al., 1997). The forest managed by PSML is distributed over several management units referred as Tapadas. Two of them, Tapada das Roças and Tapada do Mouco, are located side by side and were selected as the study area.

2.2. Forest inventory

Nine forest strata were identified in the study area, as combinations (pure or mixed stands) of *Acacia* Mill. spp., *Eucalyptus* L'Hér. spp., *Pinus pinaster* Aiton, and *Pittosporum undulatum* Vent. A stratum with a mixture of species was identified and designated as Mixed. In some cases, in this stratum, it was only possible to identify the genus of the tree.

The forestry inventory took place in spring 2011 after the harvest of most of the acacia trees; 26 circular plots of 500 m^2 distributed proportionally to the area of the different strata were measured, assuming one plot per hectare but with a minimum of two plots per stratum (see Table 2). Any individual with a height greater than or equal to 2.0 m was considered a tree. In each inventory plot two perpendicular measurements of the diameter at breast height (*dbh*) and total height of each tree with a *dbh* larger than 4.5 cm were measured (Table 1). Trees with a diameter smaller than 4.5 cm were counted (per species) and grouped in one class; average values of diameter and height were assigned this class. Tree age was not evaluated.

Samples of the litter of the forest floor, after the removal of live herbaceous plants, were collected in four areas of 900 cm^2 in each inventory plot, spaced 2 m from the plot center, and defined according to the cardinal directions. Soil samples for organic carbon determination at a depth of 30 cm were obtained at the same location where litter samples were collected. These samples were mixed to obtain one composite per inventory plot. A soil sample of about one kilogram was taken to the laboratory.

2.3. Estimation of carbon stock (baseline)

The estimation of carbon stock in the study area in spring 2011 implied the estimation of the following pools:

(a) Total biomass, defined as the sum of above and belowground biomasses.

Biomass values were initially estimated at tree level using several allometric equations from literature (Nabuurs et al., 2003; Montero et al., 2005; Zianis et al., 2005; Tomé et al., 2007; Faias, 2008; Ruiz-Peinado et al., 2011, 2012; Soares and Tomé, 2012), then summed over each plot and reported to the hectare (Eq. (1)). Biomass at the stratum level was based on the mean biomass value per hectare for the stratum multiplied by the stratum area and biomass in the study area was the sum of the biomasses considering all the strata (Eq. (2)).

$$W_{plot} = \frac{10}{plotarea} \sum_{i=1}^{n} (w_{ai} + w_{bi}) \quad (1)$$

$$W_{area} = \sum_{j=1}^{nstrata} \left[\left(\frac{\sum_{i=1}^{m} W_{ploti}}{nplots} \right)_j \times area_{stratumj} \right] \quad (2)$$

Table 1
Characteristics of the species identified in the inventory of the study area.

Species	ntrees	*dbh* (cm)			*h* (m)		
		min	mean	max	min	mean	max
Acacia Mill.	20	5.4	20.9	69.8	5.9	13.4	27.7
Araucaria Juss.	1	31.8	31.8	31.8	14.0	14.0	14.0
Arbutus unedo Tourn.	23	4.6	6.3	12.2	3.4	5.0	6.2
Castanea sativa Mill.	5	7.9	10.0	11.5	8.6	9.9	13.1
Cupressus Tourn.	13	5.4	12.0	28.7	4.0	7.5	14.5
Erica arborea L.	7	4.5	4.9	5.7	3.6	4.7	5.2
Eucalyptus L'Hér.	713	4.6	15.6	62.2	3.0	17.1	36.2
Pinus pinaster Aiton	487	4.7	20.0	46.7	4.0	14.5	21.6
Pinus pinea L.	28	5.2	8.6	14.2	3.1	5.0	6.6
Pittosporum undulatum Vent.	118	4.5	9.6	23.0	4.7	10.2	17.8
Platanus Tourn.	1	39.6	39.6	39.6	22.0	22.0	22.0
Quercus Tourn.	13	5.5	15.8	46.2	3.0	9.5	17.2
Quercus suber L.	12	5.1	15.4	41.8	2.9	6.6	13.8
Robinia pseudoacacia L.	3	9.4	14.3	18.6	8.0	10.7	13.9

ntrees is the number of trees per species; *dbh* is diameter at breast height; *h* is total tree height.

Table 2
Strata characterization in spring 2011 (baseline).

Stratum	EgAc	EgEg	EgPp	EgPu	PpEg	PpPp	PpPu	PuEg	Mixed
nplots	–	8	2	2	2	6	2	2	2
area (ha)	0.175	9.873	0.749	1.528	0.273	5.626	0.225	0.397	0.268
N (ha^{-1})	1340	1340	1660	1880	640	1067	940	630	130
dg (cm)	17.0	17.0	16.8	17.3	25.7	20.4	23.7	19.2	34.4
hm (m)	16.9	16.9	14.6	14.8	19.5	12.9	13.5	12.2	17.2
C (Mg ha^{-1})	125.7	125.7	112.1	141.8	138.0	89.0	125.7	59.7	48.0

Ac, *Acacia* spp.; Eg, *Eucalyptus globulus*; Pp, *Pinus pinaster*; Pu, *Pittosporum undulatum*; XY, represents mixed stands where X is the most common species and Y is the second most common species; XX, represents pure stands of the species X; nplots is the number of inventory plots; *N* is the number of trees; *dg* is the quadratic mean diameter; *hm* is the mean height; *C* is the total carbon.

Where W_{plot} is the total biomass at plot level (Mg ha^{-1}), *wa* is the aboveground biomass at tree level (kg), *wb* is the belowground (root) biomass at tree level (kg), *n* is the number of trees per plot, W_{area} is the total biomass in the study area (Mg), *m* is the number of inventory plots per stratum.

When there was no tree biomass equations for a given species, equations for similar species in shape, size and growth rate were used.

(b) LiBTerfall biomass.

At the laboratory, the samples of the litter of the forest floor were oven-dried at 70 °C to a constant weight and the respective biomass per unit area was calculated. Values were initially estimated at the plot level and biomass at the stratum level was based on the mean biomass value per hectare for the stratum, multiplied by the stratum area.

(c) Soil carbon.

At the laboratory values of fine earth and gross elements (2 mm sieve) were evaluated in the soil samples. Soil organic carbon was determined by wet oxidation using the Springer and Klee method modified by De Leenher and Van Hove (1958). The amount of carbon in the soil was calculated as the product of carbon concentration and soil mass. Values were initially estimated per hectare and carbon at the stratum level was based on the carbon value per hectare multiplied by the area.

Carbon was assumed, for all the pools, except soil, to represent 50% of the biomass (Nabuurs et al., 2003).

2.4. Native species

During autumn 2011, several native species were planted in gaps existing in the entire area of both Tapadas: *Arbutus unedo* Tourn., *Castanea sativa* Mill., *Corylus avellana* L., *Crataegus monogyna* Jacq., *Frangula alnus* Mill., *Fraxinus angustifolia* Vahl, *Ilex aquifolium* L., *Juglans nigra* L., *Laurus nobilis* L., *Malus sylvestris* (L.) Mill., *Prunus avium* L., *Prunus lusitanica* L. subsp. *lusitanica, Pyrus bourgaeana* Decne., *Quercus pyrenaica* Willd., *Quercus robur* L., *Quercus suber* L., *Salix atrocinerea* Brot., *Sambucus nigra* L. and *Sorbus domestica* L. The number of trees was recorded by species, in each stratum.

It was assumed that all the 11,546 native trees that were planted in 2011 had, five years later, reached the *dbh* level (1.30 m height). Tree diameters were estimated based on information collected from databases available at Instituto Superior Agronomia. For the species for which there was no information, values from species with similar shapes and growth rates were assigned. Tree heights were estimated with tree species specific height-diameter equations (Tomé et al., 2007; Trasobares et al., 2007). Tree allometric equations were used to estimate tree biomass. Total biomass and carbon of the study area were estimated following the procedure described above.

2.5. Estimates of carbon for a 30-year horizon

Based on the management plan defined by PSML, the evolution of the carbon stock for a 30-year horizon for the situation characterized in the baseline (spring 2011) was analyzed. The management plan of the study area was defined with the aim of eliminating the acacia trees (especially because of their characteristics as an invasive species (Weber, 2003)) and reducing the density of eucalyptus and pine trees. Thus, the plan defines:

- cutting all mature acacia trees in a 10-year horizon;
- thinning of 30% of eucalyptus and pine trees in a 10-year horizon;
- thinning of 70% of the remaining eucalyptus and pine trees in a 20-year horizon.

Age-independent individual tree diameter growth equations (Trasobares et al., 2007) were used to follow the evolution of tree *dbh*. Tree heights were estimated with height-diameter equations

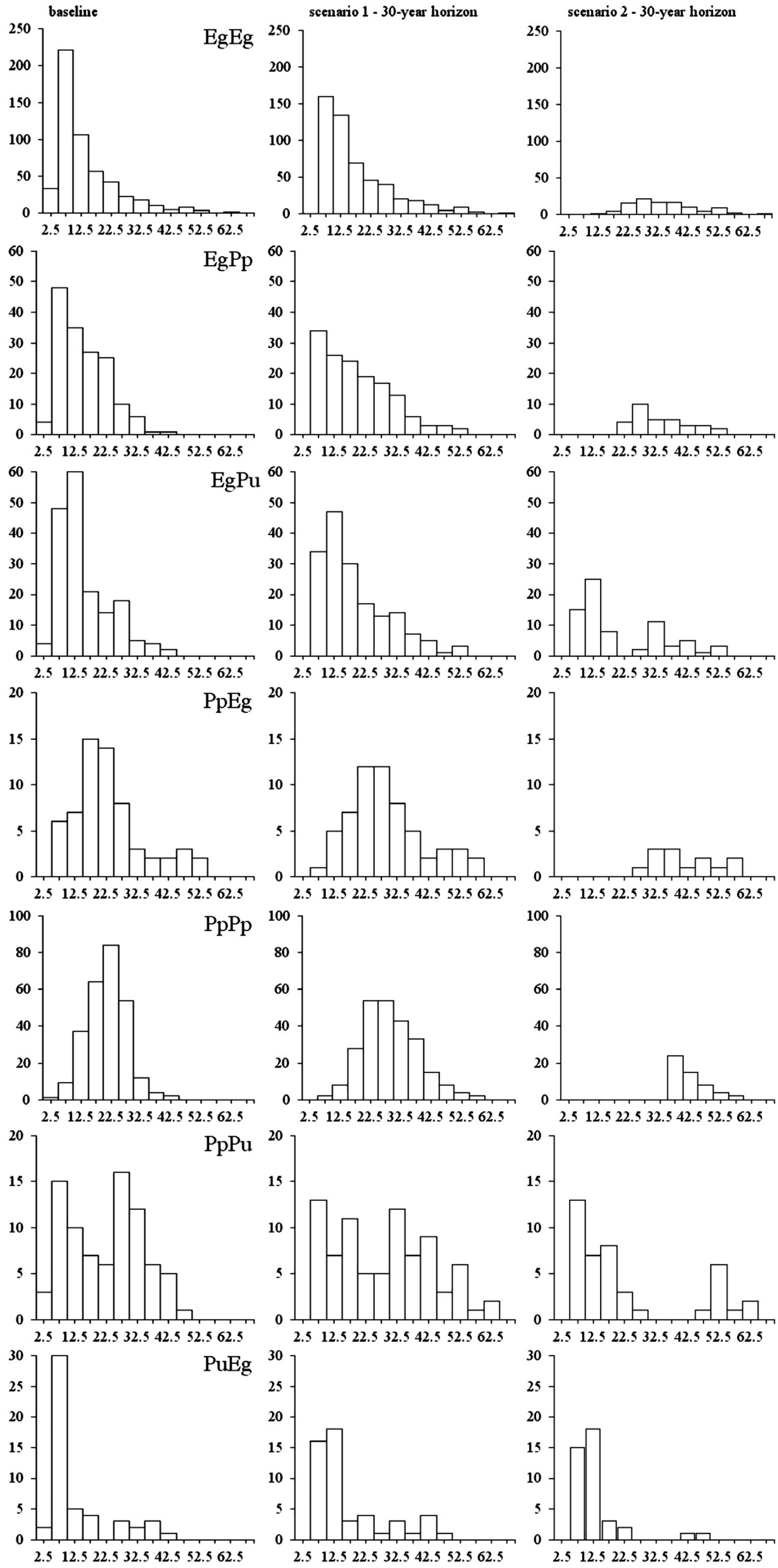

Fig. 1. Tree diameter distribution per stratum in the baseline and at the end of the 30-year horizon of scenarios 1 and 2. Scenario 1: maintenance of acacia, eucalyptus and pine trees and no plantation of native trees; Scenario 2: removal of acacia, eucalyptus and pine trees but native tree species planted in autumn were not considered. Eg, *Eucalyptus globulus*; Pp, *Pinus pinaster*; Pu, *Pittosporum undulatum*. Amplitude of each diameter class: 5 cm.

(Tomé et al., 2007) and tree allometric equations were used to estimate tree biomass (above and belowground) (Nowak et al., 2002; Nabuurs et al., 2003; Montero et al., 2005; Zianis et al., 2005; Tomé et al., 2007; Ruiz-Peinado et al., 2011, 2012). Total biomass and carbon of the study area were estimated following the procedure described above.

The estimates of carbon along the 30-year horizon were based on the following assumptions:

- absence of natural mortality based on the low density observed in the inventory plots and the non-existence of pests and diseases with relevant expression;
- control of the natural regeneration of acacias by foliar herbicide applications and manual control;
- elimination of acacia trees in a 10-year horizon;
- reduction of the density of the eucalyptus and pine trees on two occasions: 10-year and 20-year horizon; thinnings from below were applied by removing smaller diameter trees first to minimize the deterioration of visual quality;
- no influence of mature trees on the growth of the native planted trees as they were planted in existing gaps;
- all native trees planted in 2011 had, five years later, values of *dbh*;
- litter and soil carbon stocks were assumed to be constant for the 30-year horizon. Values to the entire study area are 340.3 Mg and 1713.8 Mg, respectively. This assumption will be tested by monitoring litter and soil carbon in future inventories.

Three scenarios were considered:

Scenario 1: evolution of the carbon stock of the forest characterized in spring 2011 (maintenance of acacia, eucalyptus and pine trees and no plantation of native trees); Scenario 2: evolution of the carbon stock of the forest characterized in spring 2011 with the removal of acacia, eucalyptus and pine trees in accordance with the management plan presented above; and Scenario 3: the same as scenario 2 but also considering the growth and development of native tree species planted in autumn 2011.

Results are presented for years 5, 15 and 30 of the 30-year horizon.

3. Results

Table 2 presents the characterization of the study area per stratum in spring 2011 (baseline), regarding stand density, mean tree dimensions and carbon per hectare.

The stratum EgAc was inaccessible due to the large amount of understory and average values of carbon per hectare of the stratum EgEg were used. The stratum of pure eucalyptus (EgEg) had the largest contribution (1241.0 Mg) to the overall amount of carbon, which was associated with the high area value and not to large trees. In this stratum, the carbon per tree was 93.8 kg, which was lower than that observed in the PpPu stratum (C/tree=133.7 kg) which presented a similar value of carbon per hectare (125.7 Mg ha^{-1}). The characteristics of the species were reflected in these values. *P. pinaster* (Pp) and *P. undulatum* (Pu) are species that, in this area, presented a lower *h*/*dbh* ratio and lower height values when compared with *E. globulus* (Eg) (Table 1) and were visually less dominant in the landscape. This was shown in the strata PpPp and PuEg where average trees were characterized by large diameter (20.4 and 19.2 cm, respectively) and relatively low height (12.9 and 12.2 m, respectively) associated with 83.4 and 94.8 kg of carbon per tree. The PpEg and Mixed strata had the highest values of carbon per tree: 215.6 kg and 369.2 kg, respectively, reflecting, in both cases, the large size of the trees. In the Mixed stratum, trees belonging to the genus *Acacia*, *Quercus*, *Araucaria*, *Platanus*, *Robinia* and *Cupressus* were inventoried and several dominant trees were measured, including Trees 46 and 70 cm in diameter.

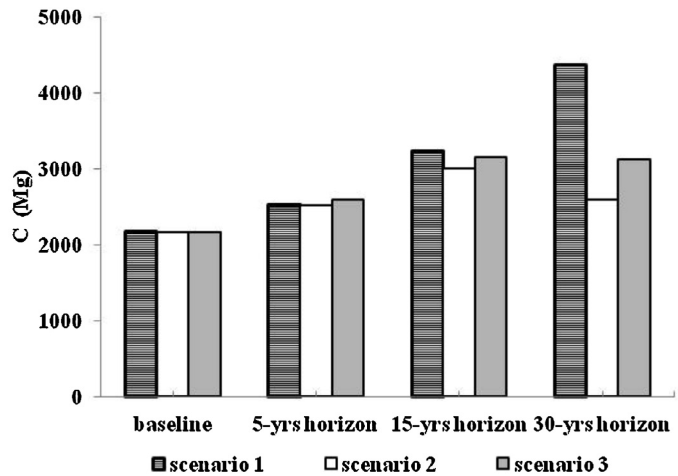

Fig. 2. Estimation of carbon stock in the study area considering only the tree pool in the three scenarios. Scenario 1: maintenance of acacia, eucalyptus and pine trees and no plantation of native trees; Scenario 2: removal of acacia, eucalyptus and pine trees but native tree species planted in autumn were not considered; Scenario 3: the same as scenario 2 but considering the native tree species.

Fig. 1 presents the diameter distribution of trees per stratum in the baseline and at the end of the 30-year horizon of scenarios 1 and 2. The effects of the dynamic of the several strata after 30 years can be observed.

In scenario 1, there was no change in the number of trees due to the assumption, confirmed by local observation, of no occurrence of natural mortality and because thinnings were not applied. The amplitude of the *dbh* distribution was increased when compared with the baseline, reflecting the growth of dominant trees and the suppression of dominated trees as a consequence of the characteristics of the study area.

In scenario 2, thinnings focused on eucalyptus and pine trees. In Fig. 1, in the mixed stands where the *P. undulatum* was present (EgPu, PpPu, and PuEg), it was possible to identify two groups of trees along the *dbh* distribution, after 30 years. The Pu trees were located in the lower *dbh* classes, reflecting the low growth rate that characterizes the species, and the Eg and Pp trees were located in the dominant *dbh* classes, reflecting the type and intensity of thinnings. The option by low thinning was a good decision to maintain the visual appeal of the landscape because dominant trees were maintained in the stand, minimizing the impact of species replacement. The impact of the thinnings on the carbon stock per stratum is presented in Table 3, showing a reduction in carbon associated with the harvest of acacias, eucalyptus and pine trees. In the first thinning (10-year horizon), 30% of the eucalyptus and pine trees were harvested, and five years later, the difference in the study area associated with the tree pool between scenario 1 and 2 was only 7% of the total carbon estimated in scenario 1 (Fig. 2 and Table 3). However, this difference increased significantly five years after the second thinning (40.5%).

The contribution of native tree species planted in autumn 2011 to the carbon stock is shown in Fig. 2, corresponding to the difference between the carbon stock in scenarios 2 and 3.

Most of the native species were characterized by relatively small (maximum) height values, as found in the literature (González, 2010), e.g. 10 m for *A. unedo*, 6 m for *C. avellana*, 20 m for *P. avium*. Thus, it was impossible to achieve carbon stock values previously associated with acacia, eucalyptus and pine trees (scenario 1, 30-year horizon, 4360.9 Mg). In scenario 3, the effect of the first thinning on the carbon stock (visible in the 15-year horizon) was

Table 3
Evolution of carbon per stratum (Mg) and to the entire area of study (Mg) in scenarios 1 (baseline) and 2 (with thinnings at 10 and 20-year horizon).

Stratum	EgAc	EgEg	EgPp	EgPu	PpEg	PpPp	PpPu	PuEg	Mixed	Total
year	scenario 1									
5	26.6	1395.3	101.7	249.0	42.1	631.7	33.8	26.8	14.1	2521.1
15	30.2	1700.9	138.3	313.3	51.0	901.1	44.8	33.3	16.8	3229.7
30	39.6	2218.5	197.0	418.1	65.7	1295.7	60.8	44.6	21.0	4361.0
	scenario 2									
5	26.6	1395.3	101.7	249.0	42.1	631.7	33.8	26.8	14.1	2521.1
15	29.1	1639.4	129.9	294.9	45.5	791.8	39.3	24.1	9.2	3003.2
30	26.4	1491.5	117.0	246.5	28.1	621.8	28.4	20.2	12.6	2592.5

minimized by the growth of native species, and the effect of the second thinning (visible in the 30-year horizon) was also attenuated by the growth and development of those trees, reaching carbon values similar to those seen in the 15-year horizon (Fig. 2). So, at the end of the 30-year horizon, the stratum of native species could still reduce the carbon stock difference between scenario 1 and scenario 2 by 523.7 Mg, which corresponds to 30% of the carbon losses associated with the elimination of acacia trees and thinnings of pine and eucalyptus trees. These native species contributed to the study area not only in terms of carbon but also by increasing biodiversity because strata dominated by one or two species were changed to a mixed forest, contributing to the valorization of the landscape (Roloff, 2016).

4. Discussion

Management of forests and trees can create changes to the landscape. Urban forest structure and composition are influenced by human and management decisions (Nowak et al., 2002). The activities of urban forestry encompass design, participatory planning, sound silvicultural principles, and accepted practices as well as effective monitoring and evaluation of management activities (Auch et al., 2016). In this context, it is therefore critical that the management of production and scenic amenity values are planned in a balanced and integrated manner. Also, forest operations should be planned in a time horizon in order to reduce the visual impact and be harmonized with the local visual character and land use patterns. The aim of managing visual landscape values in the forest practice system is to achieve an acceptable balance between protection of landscape character with good visual presentation of forest operations and the needs of efficient forest management. Priority is given to landscapes with the highest visual values, as determined by their popularity for viewing by the public, their prominence and their level of scenic attraction.

In a World Heritage Site, the presence of visitors is a determinant and their opinion as well as that of the local inhabitants is fundamental to obtaining the balance necessary to the maintenance and management of this type of site. Sintra's Cultural Landscape has an important forest area that should be maintained and managed according to three issues: (1) landscape aesthetic, (2) promotion of native forest and (3) carbon stock value as mitigation of CO_2 emissions. From the point of view of visitors, issues (1) and (2) are the most important. But, to the forest manager, issue (3) may be the principal goal. However, the fact that the forest area is located in a Cultural Landscape obliges the forest manager to give some weight to issue (3), because it is known that the replacement of undesirable species by native species, characterized by a relatively small growth rate, imposes a cost concerning the carbon stock, with a clear decline in its values, even considering the effect of new plantations. However, the recognition of this fact does not mean that the quantification of carbon losses associated with species' replacement is not important, because it allows the manager to define an acceptable cut-off that could be used in the management of this type of area. Also, the ability to explain the consequences and the assumed and quantified costs of forest management plans in a World Heritage Site is an important part of communicating with the public, whether visitors, local inhabitants or schools. It is important to be able to show that, when the replacement of species is complete, the balance, although negative to the carbon stock, is being studied and monitored. The methodology used to estimate the carbon stock has several uncertainties that are inherent in the method used. E.g., sampling procedures, forest inventory work, the use of both empirical prediction and projection equations to estimate tree variables, and the assumptions assumed in the estimation of carbon along the 30-year horizon. However, even assuming these uncertainties, CO_2 sequestrated by native tree species is only a small percentage of the carbon lost by the cut of mature invasive and undesirable species. But this fact should be framed in long-term objectives, multiples ecosystem services, costs, and community needs (Escobedo et al., 2010).

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