ALTERFOR

Deliverable 1.1 – FMM descriptions (in report form)

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I. Forest Management Models (FMMs) description

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7. Portugal

7.1. Background and forest history

After centuries of an intensive forest wood consumption (fuelwood, building of merchant ships and warships) it is well recognized that mainland Portugal reached in the XVIII century the highest level of deforestation. However, in the second half of the XIX century Portugal was the European country that most rapidly reversed the destruction of the forest cover, mainly through plantation programs (adapted from Reboredo and Pais, 2015; Reboredo and Pais 2014; Fernow, 1907; Ribeiro and Delgado, 1868).

Radich and Baptista (2005) showed that the forested area in mainland Portugal increased from 7 % to approximately one third of the territory between 1875 and 2005. It is believed that between 1875 and 1938 the area grew 1.8 million ha mainly through the action of private owners - in the Central and Northern areas with the expansion of Pinus while in the South with the increase of the area of ‘‘montado’’ i.e., *Quercus suber* and Q*uercus rotundifolia*.

In the last three decades of the XIX century the area occupied by forests increased from 14 to 22.1 %, while the increase in cultivated land was more pronounced - from 21.3 to 35.1 %. This increase was accomplished through the conversion of uncultivated areas to arable lands (Lains, 1995). These facts were closely related with the demography - between 1864 and 1900, the population increased by approximately 1.2 million inhabitants (Reboredo and Pais, 2015).

During the 1950s and the 1960s, the emergence of the pulp and paper industry was an important factor contributing to the appearance of a new ownership type in Portugal. By then, the demand for pulp from eucalypt was too high for it to be met by family forest businesses and/or by areas with incipient management. Therefore, the pulp and paper industries developed vertically and engaged in eucalypt forest management by both renting and buying forestland. In Northern Portugal, eucalypt often replaced maritime pine deemed as more vulnerable to forest fires (Fernandes, 2008; Feliciano et al., 2015).

In 2010, forests were the main land use in the Portuguese mainland accounting for 35 % of total land area (Figure 1), around 3.15 million ha, according to the last National Forest Inventory (IFN6) (ICNF, 2013). The forest area decreased during the period 1995-2010 at a net loss rate of -0.3% per year. This decrease is related to frequent and intense wildfires. The abandonment of agriculture land (24% of total area) and the increase of shrubland and pasture land (32% of total) are also reported.

There are three major forest tree species in Portugal (Figure 1): eucalypt (Eucalyptus spp.) is the first tree species in mainland Portugal (26% of the total forest area), cork oak (Quercus suber L.) is the second (23%), followed by maritime pine (*Pinus pinaster* Aiton) (23%) (ICNF, 2013). The remaining area is occupied by holm oak (*Quercus ilex* L.) (11%), stone pine (*Pinus pinea* L.) (6%) and other broadleaf and conifer species (17%). A considerable increase in wooded areas (forest stands) with stone pine (+54%) and chestnut (+48%) has been recorded.

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The decrease of maritime pine (*Pinus pinaster* Aiton) and the expansion of eucalypt plantations were the most significant trends in the last decades. The total area of maritime pine decreased 263,000 ha between 1995 and 2010 (-13%). Most of this area changed to "shrub/grassland" (165,000 ha), 70,000 ha changed to eucalypt stands, 13,000 ha changed to urban areas and 13,700 ha were planted with other tree species.

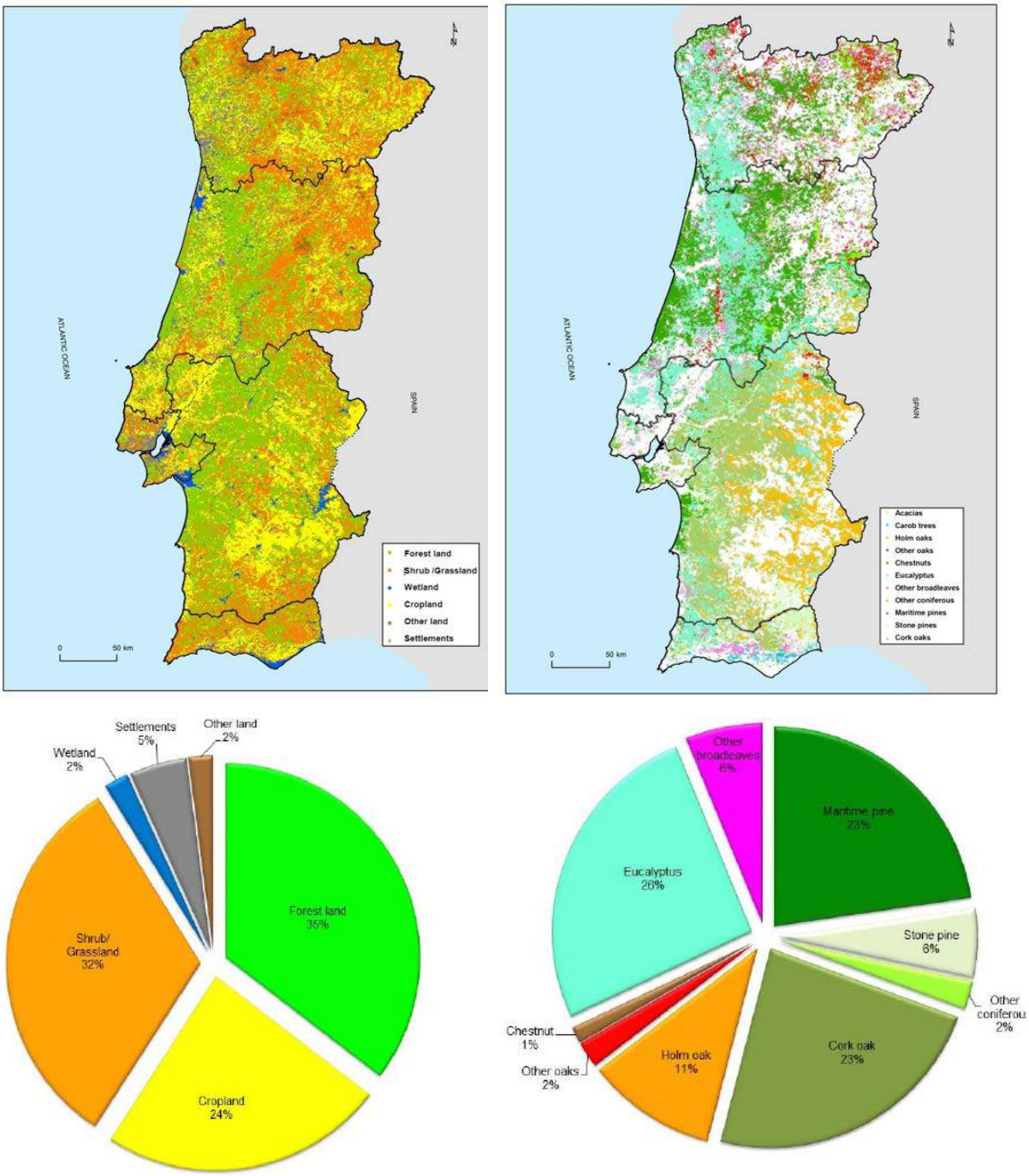

Figure 1. Land use and forest land of mainland Portugal. Source: adapted from ICNF, 2013 and Uva, 2014

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The species composition of Portuguese forests varies across regions. In the South, forest areas consist mostly of montado agroforestry systems, combining cork oak and holm oak with agriculture and grazing activities. In the North and Central regions, forests consist mostly of conifer stands (Pinus pinaster Aiton) and eucalypt stands (Eucalyptus spp.) (pure or mixed). Most Portuguese forests are primarily intended for production functions, not only for roundwood but also for pulpwood, cork and other non-wood forest products. This means that the dominant paradigm associated to forest management is the one giving priority to wood production. However multifunctional management situations can be found, especially in the montado systems, where the dominant production is based on cork extraction, also a valuable non-wood forest product.

In the North and Central regions of mainland Portugal, forest has often low profitability and tenure is highly fragmented. The proximity of forest holdings favours family engagement in forest work, which in turn influences forest management. About 47% of the non-industrial forest owners (small properties) are 70 years old or more and only undertake few types of silviculture practices. They outsource harvesting practices, particularly in the case of eucalypt stands. The forest management models where internalization of silviculture practices depends on family labour are at risk since family labour is decreasing in Portugal, and forest owners are old (Novais and Canadas, 2010). Larger private owners usually live in the city and lease out their lands to tenants or leave them under-used (Feliciano et al., 2015). Forest management is thus often incipient.

Eucalypt (*Eucalyptus globulus* Labill)

Cork oak (*Quercus suber L.*)

Maritime pine (*Pinus pinaster* Aiton)

Holm oak (*Quercus ilex* L.)

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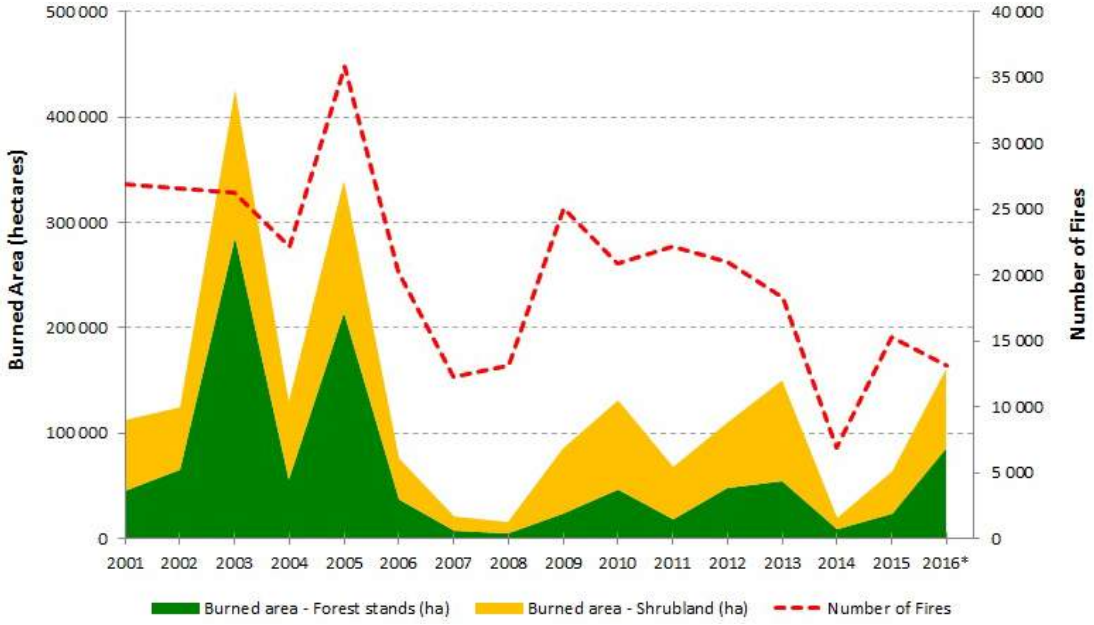
Figure 2.Main tree species in Portugal. Photo: Maria Marques.

In Portugal, wildfires have been common events, with an increasing intensity, since the 1950s. The years of 2003 and 2005 were particularly catastrophic and, since then, fires have been at the top of the agenda of public concern in Portugal. The total burned area exceeded 400,000 ha in 2003 and almost 350,000ha in 2005 (Figure 3). These events have been very important in influencing the forest policy agenda and decision-making process.



*Provisional data

Figure 3. Burned area and number of fires in mainland Portugal (2001-2016). Source: AFN, 2011 and ICFN, 2016.

The Forest Intervention Zones (Zonas de Intervenção Florestal - ZIFs) are joint management areas that must encompass at least 1,000 ha and 50 forest owners and that promote the integration of multiple owners' forest management plans to address wildfire prevention goals (Martins and Borges, 2007; Pinho, 2015). In February 2017, there were 183 ZIF in mainland Portugal, representing more than 21,000 forest owners, responsible for joint management of areas extending over 940,432 ha (ICNF, 2017b) and corresponding to 30% of the country's forest area and about 11% of the country's mainland area. The ZIFs typical tenure heterogeneity derives from the number of ownership types involved e.g., nonindustrial private forests, industry and community/municipalities. ZIFs have a management board that may consist of a forest owners association. This management board is responsible for developing the ZIFs forest management plans. Typically, the management board holds meetings with representatives from each ownership type as well as with representatives from other stakeholders e. g., other non-governmental organizations (NGOs), forest service, to engage them in the development of the plan (Borges et al. 2017). The forest owners with forest stands with-in the perimeter of a ZIF are compelled to follow the forest management plan after its approval by the general assembly of the ZIF and by the National Forest Authority (Fernandes, 2008; Marques, 2011; Valente, 2013; Feliciano et al., 2015).

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Table 27. Data about mainland Portugal and the Vale do Sousa CSA.

	Vale do Sousa CSA4	North Region (NUTS II)5	Mainland Portugal6
Total area (ha)	14,840	2,128,629	8,908,893
Forestland (ha)	14,474	680,659	3,154,800
Forestland cover (%)	97	32	35
Productive forestland (ha)1	14 474	-	-
Productive forestland cover (%)	97	-	-
Average volume (m3ha-1)2	-	-	-
Site productivity (m3ha-1year-1)2	-	-	-
MAI 2011-2015 (m3ha-1year-1)2	-	-	-
Ownership forestland (%) Companies Private Communal and Public	 20 75 5	 - 86 14	 7 78 16
Protected areas (%)2,3	3	24	22

[1] >1m3ha-1year-1

[2] On productive forestland,

[3] Formal and voluntary protection,

[4] The data is reference to 2012,

[5] The data is reference to 2005.

[6] The data is reference to 2010.

7.1.1. Ownership

State ownership represents only 2% of the Portuguese forest land and communal land 14% of the total forest area. Private ownership accounts for 85% of forest land and 70% of it has less than 4 ha, while only 1% of it has 100 ha or more (ICNF, 2017a; Louro, 2015), Table 27 and Figure 4.

In North-ern and Central Portugal most forest holdings are less than 0.5 ha and are occupied by maritime pine and eucalypt. Land tenure is heterogeneous and highly fragmented. The Vale do Sousa Case Study Area (CSA) reflects this situation. Forest estates in the CSA are frequently scaled with dimensions of 1.5 ha and scattered over multiple blocks. The CSA area extends over 14,840 ha distributed over 360 private owners, who are members of the ZIF.

Under these tenure conditions, effective intervention to protect forests and increase its profitability is made possible through cooperation within forest owners associations and through the establishment of partnerships (e.g. ZIFs). This is a precondition for the effectiveness of landscape-level management planning and the sustainability of the provision of ecosystem services. Those institutions support active management and protection of private and communal forests. The Portuguese CSA is characterized by such an institutional framework - an active and representative forest owner association the Vale do Sousa Forest Owners' Association (AFVS, Associação Florestal do Vale do Sousa) and a ZIF.

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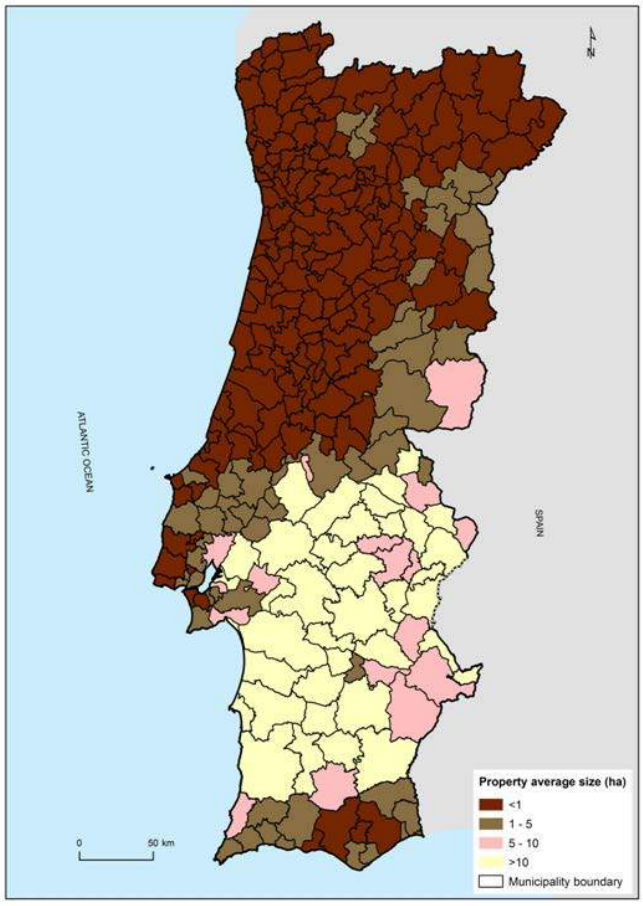

Figure 4. Forest ownership in Portugal. Source: adopted from DGCI, 2006 in EFN, 2015.

7.1.2. Nature conservation

The geographical position of mainland Portugal, covering two biogeographic regions - Atlantic and Mediterranean – leads do ecological diversity. Biodiversity levels are high in 22% of the country's territory. The national protected areas network has the following typologies: National Park (1), Natural Park (13), Natural Reserve (9) and Protected Landscape (2). This network represents 7.5% of the country's territory. All protected areas at the national level have a management plan. The Natura 2000 European network represents 62 sites, of which 60 have already been recognized as Sites of Community Importance (SCIs), and 42 Special Protection Zones (SPAs) (ICNF, 2017a).

7.2. The case study area

The Vale do Sousa CSA covers the southern part of the Sousa Valley, and extends over an area of 14,840 ha corresponding to the following ZIF separated by the Douro river: Entre-Douro-e-Sousa (north of the Douro river) and Paiva (south of the Douro river). The total number of forest owners who are members of these ZIF is 360, but the area mentioned above includes other forest owners who have land inside the ZIF, but are not members yet.

The Vale do Sousa CSA is representative of Portuguese conditions in terms of ownership type and structure as well as of species composition: over 85% of the forest area in Portugal is privately

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owned (mostly by small non industrial private forest owners) and eucalypt and maritime pine are two of the main forest species. Its ecological endowment does not favour the plantation of species dominant in Southern Portugal; cork oak (Quercus suber) and holm oak (Quercus ilex). The difference between the CSA and the entire country regarding the coverage of FMM is thus explained first by its location in Northern Portugal. In this region eucalypt productivity is higher. Further, in a ZIF (joint management area) management is prone to be more active. Nevertheless, since the 80s a clear trend exists of declining pine and mixed pine and eucalypt areas, and of increasing eucalypt areas. Other areas and sub regions are going through earlier stages of the same trend. Moreover, as ZIFs are being actively promoted by public policy the representativeness of the CSA will tend further to in-crease. The CSA sets a model that might be followed by other forest areas and ZIFs in the region.

The Vale do Sousa Forest Owners' Association (AFVS) is the only forest owners' association in the case study area. Therefore, it is the only voice representing the forest owners in the dialogue with public authorities and other stakeholders. It is, also the most important organization providing technical support to forest owners, and the only one having forest sapper brigades to carry on preventive silvicultural works for reducing the risk of forest fires.

The CSA socio-demographical environment is heterogeneous, since it includes two contrasting areas on both river Douro banks. Municipalities to the North (Paredes and Penafiel), at a short driving distance from the major urban area of Porto are inhabited by many urban commuting residents, while the municipality to the South (Castelo de Paiva) contrast to these as a typical North-Western Portugal rural and lowly populated area with less commuting residents. Also the latter is still losing population while the population in the former is increasing. Nevertheless, as the municipalities to the North of Douro demographically outnumber Castelo de Paiva, the region as a whole is still increasing its population numbers.

The Vale do Sousa CSA is managed by the ALTERFOR local stakeholder, AFVS, (Borges et al. 2017) and it encompasses 360 landowners. Community (local parish) property accounts for 35% of the Vale do Sousa CSA. Medium and large private properties (area greater than 5 ha) extend over 60% of the Vale do Sousa area. The remaining 5% is owned by small or very small forest owners. Eucalypt pulp-wood and maritime pine saw logs rank very high in the list of ecosystem services provided by Vale do Sousa CSA. This list also includes hardwood (chestnut) saw logs and carbon storage (INTEGRAL, 2015). The landscape-level FMM results thus from the spatial distribution of stand-level FMM agreed by the ZIF's forest owners. Of concern and being a focus of the research within ALTERFOR is the impact of landscape and stand-level FMMs on the provision of biodiversity and regulatory services (wildfire).

7.2.1. Land Area/ forest area proportions

The Vale do Sousa CSA was chosen for its representativeness of forest management practices and forest ownership structure of the North-Western Portugal forest, were the topography is typically very irregular, the forest estates typically very small scale and scattered over multiple blocs, and are privately owned. The average rainfall is high (last 30 years averaged 1240 mm yearly), but unevenly distributed round the year, with three very dry months (June, July and August) with average rainfall of 31.1 mm, and three very wet months (October, November and December) with average rainfall of 170.4 mm. Soils are mostly poor, well drained and thin. The average

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temperature varies annually between 9.5ºC in January and 20.8ºC in August. The predominant forestry species are Pinus pinaster Aiton and Eucalyptus globulus Labill in pure and mixed stands.

Tree species

In the Vale do Sousa CSA, forestry is the main land use. The CSA has a high productive potential for species with country-wide importance: blue gum/ eucalypt (Eucalyptus globulus Labill) and maritime pine (Pinus pinaster Aiton). Its forests are thus mainly dominated by eucalypt (pure and mixed), followed by maritime pine. The proportion of eucalypt is larger in the CSA than in the country and in the north-west region (Table 31) but is still representative of the sub-region reflecting its high productivity and the decrease of the maritime pine area.

Eucalypt pulpwood and maritime pine saw logs rank very high in the list of ecosystem services provided by the Vale do Sousa CSA. On this, the CSA diverges from other forested areas in North-Western Portugal, where the importance of the eucalypt area is not as important, and maritime pine is more important, but this situation has been changing towards a pattern closer to the situation existing in Vale do Sousa. Gonipterus platensis disease constitutes a major problem for the eucalypt forest in the CSA.

Table 28. Tree Species important in Portugal and the Vale do Sousa CSA.

Species (Latin name)	Proportion (% total volume)			Proportion (% of species area)		
	CSA[1] (Vale do Sousa)	North Region (NUTS II)[2, 3]	Country[3] (Mainland Portugal)	CSA[4] (Vale do Sousa)	North Region (NUTS II)[2, 3]	Country[3] (Mainland Portugal)
Eucalyptus globulus Labill	90.46	16.15	17.27	66.00	13.70	16.38
Eucalyptus globulus Labill **x** Pinus pinaster Aiton	6.22	N/A	N/A	17.00	N/A	N/A
Pinus pinaster Aiton **x** Eucalyptus globulus Labill	3.29	N/A	N/A	16.00	N/A	N/A
Castanea sativa Mill	0.04	2.39	0.65	1.00	3.13	0.70

[1] The data is referenced to 2012. No meaningful changes have been reported by AFVS.
[2] NUTS II.
[3] The data is reference to 2005.
[4] The data is reference to 2010.
N/A: not applicable (there isn't available the information about the dominated species).

7.2.2. Site productivity and tree species

There is a large difference in growth and yield of tree species. On the best sites eucalypt reaches 22-25 meters dominant height in 10 years (Table 30) while chestnut needs 45 years to reach approx. the same height (Table 31) and maritime pine reaches 30 m in 50 years (Table 29).

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Chestnut is mainly growing on the best sites, while maritime pine and especially eucalypt have a more even distribution over all sites.

Table 29. Maritime pine site productivity.

Maritime pine (*Pinus pinaster* Aiton)		
Index value	Height (of dominant trees) at **50 years** (m)	% of area with maritime pine
1 (inferior)	14	5
2 (low)	18	6
3 (medium)	22	28
4 (high)	26	33
5 (superior)	30	29

Table 30. Eucalyptus site productivity.

Eucalyptus (Eucalyptus globulus Labill)		
Index value	Height (of dominant trees) at **10 years** (m)	% of area with eucalyptus
1 (inferior)	13	12
2 (low)	16	24
3 (medium)	19	30
4 (high)	22	24
5 (superior)	25	8

Table 31. Chestnut site productivity.

Chestnut (*Castanea sativa* Mill)		
Index value	Height (of dominant trees) at **45 years** (m)	% of area with chestnut
1 (inferior)	14	0
2 (low)	16	0
3 (medium)	18	23
4 (high)	22	29
5 (superior)	24	49

7.2.3. Forest fires

Wildfires have been very frequent in the three municipalities over which the Vale do Sousa CSA is distributed (Figure 5). There were years with particularly high incidence, such as 2003, 2005, 2010 and 2013, each of these years with more than two thousand hectares of burnt forest area. The year of 2005 was particularly catastrophic. The total burned area in the municipalities of Paredes,

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Penafiel and Castelo de Paiva, exceeded 9,000 ha in 2005 (Figure 6), 57% of this burned area was in the CSA. These were years where the same high incidence of fires also existed all over the country and not only in Vale do Sousa. On the whole, over the period 2001/ 2015 the total forest burnt area amounted to 26,395 ha. Further, there has been a recurrence of one large fire (fire with more than 1000 ha of burnt area) in the CSA almost every two years. These events have had a great influence on management decisions taken by forest owners. They prefer eucalypt stands, because of their shorter rotation and because the income loss is smaller in the case of wildfire occurrence. Other forest species with longer rotations, e.g. maritime pine, chestnut, rank lower in forest owners' preferences.

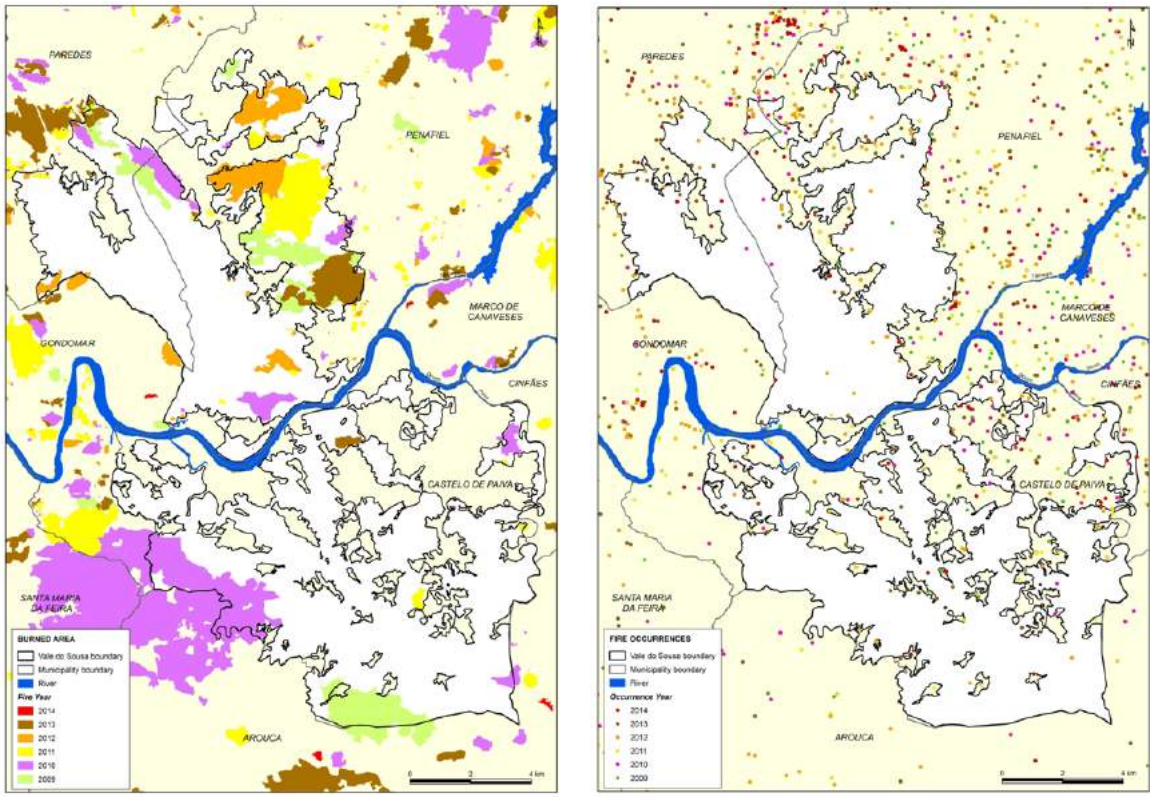

Figure 5. Distribution of burned are and fire occurrences in the Vale do Sousa CSA (2009-2014). Source: ICNF, 2016b.

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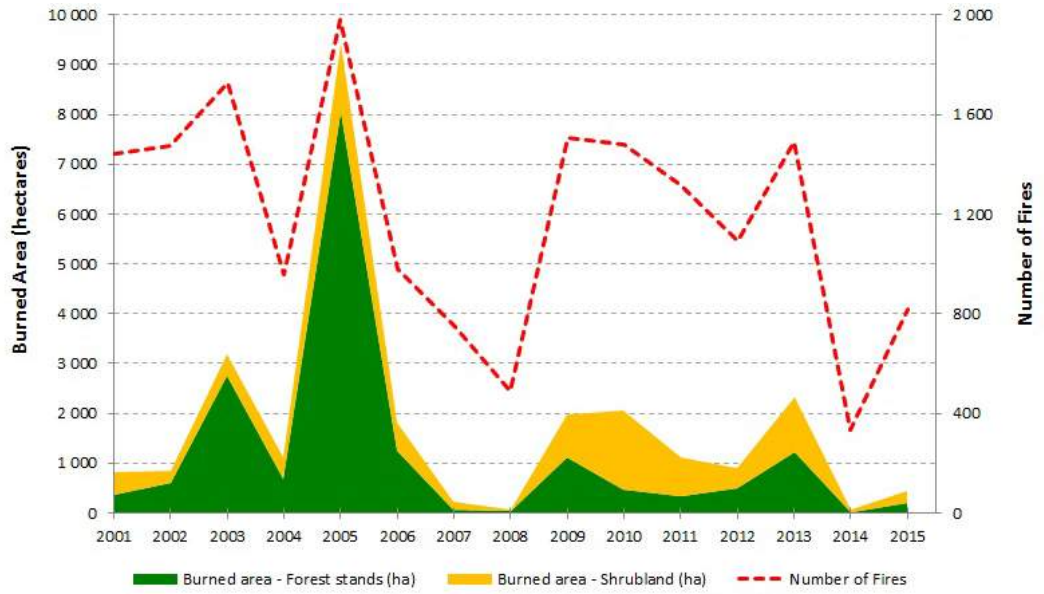

Figure 6. Burned area and number of fires in the municipalities of Paredes, Penafiel and Castelo de Pavia (2001-2015). Source: ICNF, 2016b.

7.2.4. FMMs used in Portugal and in the CSA

Eucalypt is the most important species in terms of distribution area both in Portugal and in the CSA. In pure stands, it covers 2/3 of the area. In a mixture with maritime pine it grows on another 1/3. Chestnut grows on a limited area, approx. 1% Table 32. In terms of volume, the dominance of eucalypt is even more striking, approx. 90% of the volume in the CSA. Of the four FMMs in the Vale do Sousa CSA three encompass eucalyptus. The fourth with chestnut. These four FMMs cover the entire CSA. There are no additional FMMs as other species present are residual.

Table 32. FMMs used in the Vale do Sousa CSA, Portugal.

Domestic name in English (FMM, Forest Management Model)	Corresponding FMM	Coverage CSA (% forestland)	Suggested coverage in CSA (%)	Coverage country (% forestland)
1. Mixed maritime pine and eucalyptus forest system, dominance of maritime pine	Clear cutting systems/ Coppice systems	16.0	3.2	4 - 7
2. Mixed maritime pine and eucalyptus forest system, dominance of eucalypt	Coppice systems/ Clear cutting systems	17.0	5.3	3 - 6
3. Chestnut forest systems for production of chestnut saw logs	Clear cutting systems	1.0	8.9	0.7
4. Eucalyptus forest system for pulpwood production	Coppice systems	66.0	82.5	16.4

Ecosystem services

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The ecosystem services (ES) provided from the four FMMs are mainly wood products, e.g., eucalypt pulpwood and pine and chestnut sawlogs (Table 33).

Table 33. Ecosystem services connected to the four FMMs in the Vale do Sousa CSA. Ranking of important ES within each FMM. No ranking between FMMs.

Forest management model (FMM)	Eucalypt pulpwood	Pine sawn timber	Standing Volume (wood)	Carbon stock storage	Chestnut sawlogs
1. Mixed maritime pine and eucalyptus forest system, dominance of maritime pine	1	1	4	3	
2. Mixed maritime pine and eucalyptus forest system, dominance of eucalypt	1	1	4	3	
3. Chestnut forest systems for production of chestnut saw logs			3	2	1
4. Eucalyptus forest system for pulpwood production	1		3	2	

Size of clearcuts in the CSA

The Tâmega Regional Forest Plan (PROF-T), approved in 2007 by Minister of Agriculture (www.icnf.pt/portal/florestas/profs/tameg), has a recommendation stating that in areas without a Forest Management Plan (PGF) contiguous clearcut areas should not exceed 10 ha. Typically, in the CSA, harvest areas in properties with Forest Management Plans do not exceed 50 contiguous hectares.

For the different FMMs, data about clearcut areas shows that there is a large variation between smallest and largest clear-felled areas (Table 34). In average the largest clear-felled areas are found in the eucalypt FMM.

Table 34. Size of clear-felled area at one-time in the Vale do Sousa CSA.

Forest management model (FMM)	Minimum area (ha)	Maximum area (ha)	Mean area (ha)
1. Mixed maritime pine and eucalyptus forest system. dominance of maritime pine	0.2	47.5	2.8
2. Mixed maritime pine and eucalyptus forest system. dominance of eucalypt	0.1	35.2	2.7
3. Chestnut forest systems for production of chestnut saw logs	0.5	14.8	2.2
4. Eucalyptus forest system for pulpwood production	0.5	100.2	8.2

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Rotation for different FMMs

The minimum rotation period is defined in the Tâmega Regional Forest Plan (PROF-T). Besides that, there is a stipulation stating that an authorization is needed from the National Forest Authority (ICNF) for premature cuts in maritime pine in areas greater than 2 ha and in eucalypt in areas greater than 1 ha (Decree-Law No. 173/88 of 17 May).

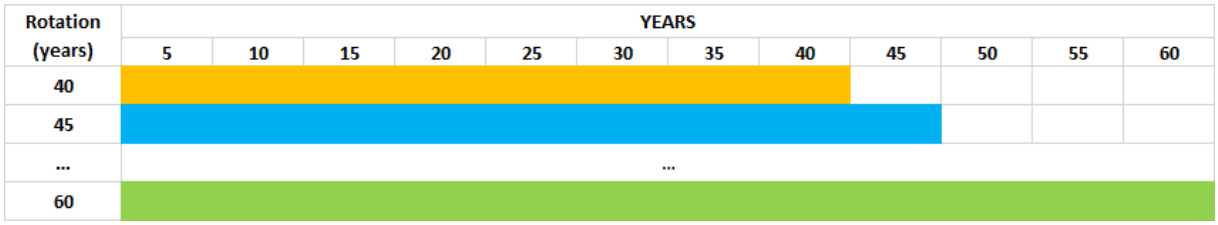

Figure 7. Maritime pine rotation (40 to 60 years).

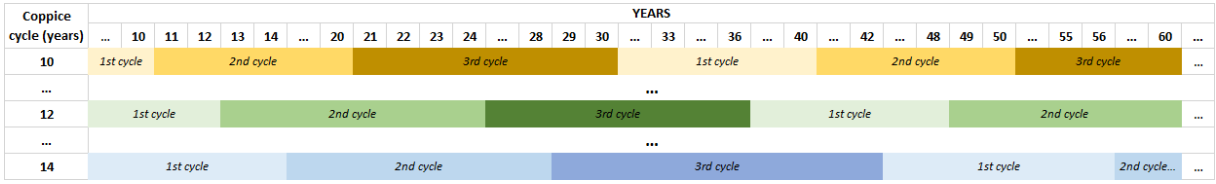

Figure 8. Eucalypt rotation (40 to 70 years).

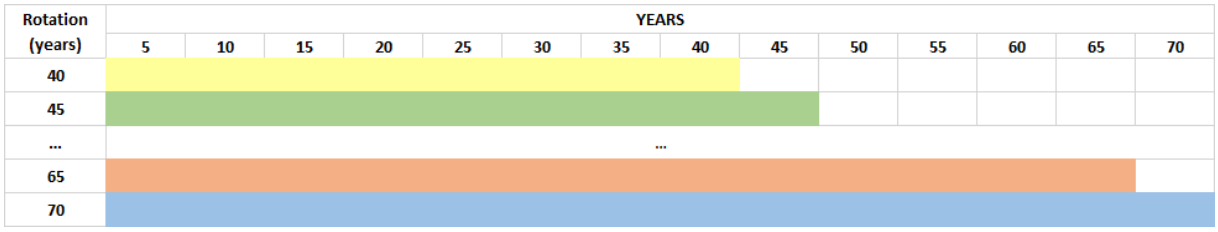

Figure 9. Chestnut rotation (40 to 70 years).

7.3. Mixed eucalypt and maritime pine (FMM1 and FMM2)

Two different models are identified both including a mixture between maritime pine and eucalypt. Maritime pine is dominant, approx. 73% of the standing volume, in the case of FMM1 while eucalypt is dominant, approx. 67% of the standing volume, in the case of FMM2. In many aspects these two systems are similar and are described together below.

Short description

Eucalypt grows fast and typically it is harvested three or more times during one rotation of maritime pine. Therefore, these mixed stands are uneven-aged over most of the planning horizon:

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only after plantation and during the first rotation of eucalypt do the stands have equal age. Stakeholders suggested the conversion to other FMMs (pure even aged stands) to promote active management and enhance productivity.

The area under the two FMMs is thus expected to decrease with conversions to pure stands (even-aged). The system today covers 16% and 17% respectively of the CSA but the recommendation is to decrease the area to about 3% and 5% respectively.

The schedule of forest operations in these FMMs may be summarized as follows:

Maritime pine: Plantation with spacing of 2200 trees per ha (2.25 m between rows and 2 m between plants). The seedlings are in a container with clod. Harvest ages: 40, 45, 50, 55 or 60 years, fuel treatments may take place every 5 years in its share of area, pre-commercial thinning at 10 years of age, commercial thinning occurring every five years in the period from 20 to 50 years of age (up to 5 years before the clearcut) based on a spacing factor (Wilson) of 0.27. Rotation ranging from 40 to 60 years.

Eucalypt: Plantation with spacing of 1400 trees per ha (3.5 m between rows and 2 m between plants). The seedlings are in a container with clod. Fuel treatments may take place every 5 years in its share of area. Rotation including three coppice cycles with 10 to 14 years. Stool thinning leaving an average of two shoots per stool at year 3 of each cycle.

In FMM1 the main species is maritime pine, approx. 8180 m3 (73%) and eucalyptus 3065 m3 (27%). In FMM2 eucalypt is the main specie approx. 14150 m3 (67%) and eucalyptus 7100 m3 (33%).

Size of clearcuts

See Table 34, page 136.

Rotation

There are regulations about rotation length. In practice the optimal stand-level rotation depends on the site index and on financial considerations. In the case of maritime pine, the target tree age ranges from 40 to 60 years, for eucalypt the target tree age ranges from 10 to 14 years, with three coppice cycles. The optimal harvest ages depend on the stand, on the ecosystem service target levels and on the management planning spatial scale (stand versus whole CSA). In practice the variation in rotation lengths is shorter, 45 to 55 years for maritime pine and 30 to 36 years for eucalypt. In the mixed forest the harvests of eucalypt and maritime pine are performed independently, when the species reach the harvest age.

Distribution over edaphic conditions, and performance

There is no information about soil moisture in the CSA. But the two systems may be found in all sites, from sites with low to high productivity.

There is a large difference in performance of the species in this mixture (maritime pine: Table 29, eucalypt: Table 30, page 133).

Mixtures Tree Species and tree species composition

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 676754.

Mixture of maritime pine and eucalyptus characterize this FMM. The current distribution of standing volume per species in each FMM over the whole CSA was reported above. In individual stands the relations differ somewhat and also over time as eucalypt is harvested thrice, during one rotation of maritime pine.

Forest regeneration

The maritime pine is planted, but some natural regeneration occurs (approximately 10% of the total maritime pine area, according to expert knowledge of Sandra Pinto from AFVS). Maritime pine seeds stored in the canopy are the main source of natural regeneration, particularly in post-fire situations, as the seed bank in the soil is scarce and not very durable. Frequently there is abundant post-fire regeneration from seed in burned adult stands. Adult trees are often killed by fire, depending on the degree of crown and cambium damage, and there is no re-sprouting in the species. So, the typical postfire management is salvage logging of burned trees and either active (plantation or seeding) or passive (natural regeneration from seeds) restoration (Moreira et al, 2017). However, due to the frequency of forest fires in the CSA, Figure 6, the natural regeneration of the maritime pine is becoming scarce in the area, forest owners choose to plant this species.

No site preparation or fencing is done or recommended.

Genetically improved and genetically modified and use of hybrids

Eucalyptus is non-native and the maritime pine is native to Europe and the Vale do Sousa CSA.

Maritime pine and eucalypt seedlings are produced from Portuguese origins that have been selected based on desired traits (e.g. quality); overall they are mostly from sources more than 100 km away from the planting spot. The main sources of seedlings for forest species are defined by National Forest Authority (ICNF): www.icnf.pt/portal/florestas/gf/ps/resource/doc/reg-prov/reg-prov12 (AFN, 2012).

The eucalypt is genetically improved and/ or clone hybrid but not genetically modified. The eucalypts that is genetically improved shows greater adaptability to different soil and climate conditions and higher wood volume and pulp yield. According to CELPA (2017), these plants show a higher growth compared to the unimproved plants (of at least 20 %), besides that improved plants have better straightness of the logs. Hybrid eucalypt results from a rootstock of eucalypt from a variety more adapted to different soils, climate conditions and resistance to diseases, such as Gonipterus platensis, and Eucalyptus globulus Labill as grafts due to its good wood qualities for pulp industry.

Pesticides and fertilizer

Pesticides are applied mainly in the eucalypt trees because of eucalypt weevil or eucalypt snout beetle pest (Gonipterus platensis). The application of herbicides is more unusual, some forest owners apply it for spontaneous plants control and wildfire risk prevention, when the stands are four/five years old.

Fertilizers are applied in all CSA FMMs at the time of planting the trees (eucalypt and maritime pine), in the first two years. In the case eucalypt trees fertilizers are also applied in the second and third cycle when the trees are two/five years old.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 676754.

Stand management

Pre-commercial thinning

In practice Pre-commercial thinning (PCT) is done in about 35-45% of the area of maritime pine in this FMMs (local knowledge from Sandra Pinto, forest engineer of AFVS). The eucalypt trees are planted at final density, so thinning and pruning are not usual during the first cutting cycle. In second and third cutting cycle there is a shoot selection on the first three years to get two shoot per stool from eucalypt.

PCT is recommended to be done in 100% of the maritime pine share of the FMM area. Maritime pine pre-commercial thinning should take place at age 10, when the tree differentiation into development classes is taking place to remove dead trees, diseased and poorly shaped trees and in order to reduce stand density. In the case of the eucalypt share of the FMM area, a shoot selection should be done rather than a pre-commercial thinning. This should take place at age 3 of the second and third rotations.

The difference results from incipient forest management by the owners, who often don't make the recommended pre-commercial thinning in the maritime pine area share.

Thinning

Maritime pine thinning occurs every five years between age of 20 up to 50 years and the last thinning takes place 5 years before clear cut.

In practice thinning is done in about 50 % of the share of area of maritime pine in this FMM (local knowledge from Sandra Pinto, forest engineer of AFVS). It is done in 0% of the eucalypt share of this FMM.

Commercial thinning of maritime pine is recommended to be done in 100% of the stands. Maritime pine thinning should take place between 20 and 50 years of age, up to 5 years before the clear-cut, typically with a 5-years interval. Commercial thinning should not be done in the eucalypt share of this FMM area.

The difference results from incipient forest management by the owners, who often don't make the recommended commercial thinning in the maritime pine area share.

Pruning

Pruning is not done.

Harvest

The maritime pine trees are typically harvested using chain saws. A harvester is used only in the case of the eucalypt share of area that is managed by the industry.

Extraction is fully mechanized (100%): skidder in areas managed by the industry and tractor with winch in the remaining areas.

Nature protection

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 676754.

The maximum contiguous harvesting area is less than 50 ha (see Table 34, page 136) to address environmental concerns with impacts of harvests.

7.4. Chestnut (FMM3)

Short description

This FMM targets the supply of chestnut timber. It provides further carbon stock storage and may also contribute to standing volume at the end of planning horizon. Its contribution to the supply of other ecosystem services (biodiversity and regulatory services) is currently being investigated. The schedule of forest operations in this FMM may be summarized as follows:

Chestnut: Plantation with spacing of 1250 trees per ha. Rotation age at 40, 45, 50, 55, 60, 65 or 70 years, thinning occurring every five or 10 years in the period from 20 to 55 years of age, based on the diameter of the trees. Fuel treatments may take place every 5 years.

At present chestnut management model cover approx. 1 % of the area. The area of mixed eucalyptus – maritime pine stands (mostly uneven-aged) and shrublands may be converted to pure (even-aged) chestnut stands to increase the supply of hardwood saw logs and the potential of the forest to pro-vide recreational opportunities.

Size of clearcuts

General information common for the CSA is given above (see Table 34, page 136). For chestnut the average clearcut area is 2.2 ha with a variation from 0.5 ha up to 14.8 ha.

Rotation

The optimal stand-level rotation age depends on the site productivity. In the case of chestnut it may range from 40 to 70 years. This complies with silviculture rules in the Tâmega Regional Forest Plan (PROF-T) that sets the minimum rotation at 40 years. The optimal harvest ages depend on the stand, on the ecosystem service target levels and on the management planning spatial scale (stand versus whole CSA). There are no mature stands of chestnut yet in CSA, so we don't know in practice what is the rotation period for chestnut.

Distribution over edaphic conditions, and performance

There is no information about soil moisture in the CSA. Chestnut is assumed to be evenly distributed over Mesic and moist conditions, on high, medium and low productive sites. There is a large difference in performance of chestnut (Table 31).

Mixtures Tree Species and tree species composition

Chestnut is growing in pure stands. In the CSA the standing volume today is 124 m3.

Forest regeneration

No site preparation or fencing is done or recommended. Chestnut trees are typically planted at final spacing, approx. 1250 trees per ha (4 m between rows and 2 m between plants). The planting should be done on deeply mobilized soil or in pits 40 cm deep. The seedlings should have an average height of 40-60 cm and bare root (Correia and Oliveira, 2003).

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 676754.

Genetically improved and genetically modified and use of hybrids

Chestnut seedlings are produced from Portuguese origins that have been selected based on desired traits (e.g. quality); overall they are mostly from sources more than 100 km away from the planting spot. The main sources of seedlings for forest species are defined National Forest Authority (ICNF): www.icnf.pt/portal/florestas/gf/ps/resource/doc/reg-prov/reg-prov12

All seedlings are genetically improved but no genetically modification is done.

Pesticides and fertilizer

Application of herbicides is unusual, some forest owners apply it for spontaneous plants control and wildfire risk prevention, when the stands are four/five years old. Pesticides are not applied in the chestnut stands.

Fertilizers are applied in all CSA FMMs, also chestnut stands, at the time of planting the trees and in the first two years.

Stand management

Pre-commercial thinning

Chestnut trees are typically planted at final spacing. Thus, there is no need for pre-commercial thinning.

Thinning

It is recommended that thinning is done in all chestnut stands between age 20 and 55 years, up to 5 years before the clearcut, typically with a 5-years interval.

It has not been possible to carry out thinning's in 100% of the area (local knowledge from Sandra Pinto, forest engineer of AFVS).

The reasons why stand are not thinned are: a) the high mortality of trees in mature stands, caused by Phytophthora cinnamomi, responsible for the ink disease, and by Endothia parasitica., responsible for the chestnut cancer and b) incipient forest management by forest owners.

Pruning

Pruning is not currently practiced.

Harvest

Chestnut stands are typical harvested with chainsaw. Extraction is done with tractor equipped with winch.

Nature protection

The maximum contiguous harvesting area is less than 50 ha (see Table 34) to address environmental concerns with impacts of harvests.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 676754.

7.5. Pure eucalyptus stands (FMM4)

Short description

Eucalyptus (Eucalyptus globulus Labill) grows in a coppice system. This FMM targets the supply of eucalypt pulpwood. It provides further carbon stock storage and may also contribute to standing volume at the end of planning horizon. Its contribution to the supply of other ecosystem services (biodiversity and regulatory services) is currently being investigated. The schedule of forest operations in this FMM may be summarized as follows:

Eucalypt: Plantation with spacing of 1400 trees per ha (3.5 m between rows and 2 m between plants). The seedlings are in a container with clod. Fuel treatments may take place every 5 years. Rotation including 3 coppice cycles with 10 to 14 years. Stool thinning leaving an average of two shoots per stool at year 3 of each cycle.

This FMM provides eucalyptus pulpwood but is also carbon stock storage and may also contribute to standing volume at the end of planning horizon.

At present pure eucalyptus cover approx. 66% of the area. It may increase as suggested recently by stakeholders. The actual percentage depends on the balancing of ecosystem services supply targets. he area of mixed stands, mostly uneven-aged, reflecting incipient management, under other FMMs (e.g. FMM1 and FMM2) and shrublands may be converted in part to pure (even-aged) eucalyptus stands (this FMM), to increase the supply of pulpwood.

The estimated volume of eucalyptus is 309160 m3 in the CSA.

Size of clearcuts

General information common for the CSA is given above (Table 34, page 136). For eucalyptus the average clearcut area is 8.2 ha with a variation from 0.5 ha up to 100.2 ha.

Rotation

The optimal stand-level rotation (coppice cycle) age depends on the site index. In the case of eucalypt coppice cycles the optimal rotation range from 10 to 14 years, with three coppice cycles, total-ly 30-42 years. This complies with silviculture rules in the Tâmega Regional Forest Plan (PROF-T) that prescribes coppice cycles ranging from 9 to 14 years. In practice rotation is slightly lower, 10 to 12 years. The optimal coppice cycle as well as the number of cycles depend on the stand, on the ecosystem service target levels and on the management planning spatial scale (stand versus whole CSA).

Distribution over edaphic conditions, and performance

There is no information about soil moisture in the CSA. Eucalyptus is assumed to be evenly distributed over Mesic and moist conditions, on high, medium and low productive sites. Eucalyptus grows fast compared to other species growing in the CSA. Dominant height after 10 year are in the same magnitude as after 45-50 years for maritime pine and chestnut (Table 29 and Table 31, page 133).

Mixtures Tree Species and tree species composition

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 676754.

In this FMM eucalyptus is growing in pure stands.

Forest regeneration

No site preparation or fencing is done or recommended. Eucalypt is typically planted at final spacing approx. 1400 trees per ha (3.5 m between rows and 2 m between plants). Seedlings must have between three and five pairs of well-formed leaves, with a height between 10 and 50 cm and a diameter greater than 2 mm.

Genetically improved and genetically modified and use of hybrids

Eucalypt seedlings are produced from Portuguese origins that have been selected based on desired traits (e.g. quality); overall they mainly originate more than 100 km away from the planting spot. The main sources of seedlings for forest species are defined by National Forest Authority (ICNF): http://www.icnf.pt/portal/florestas/gf/ps/resource/doc/reg-prov/reg-prov12

All seedlings are genetically improved and/ or hybrid but no genetically modification is done (see above).

Pesticides and fertilizer

Pesticides are applied mainly in the eucalypt trees because of eucalypt weevil or eucalypt snout beetle pest (Gonipterus platensis). The application of herbicides is more unusual, some forest owners apply it for spontaneous plants control and wildfire risk prevention, when the stands are four/five years old.

Fertilizers are applied in all CSA FMMs at the time of planting the trees and in the first two years. In eucalyptus stands fertilizers are also applied in the second and third coppice cycle when the trees are two/five years old.

Stand management

Pre-commercial thinning

A shoot selection, rather than a pre-commercial thinning, should be done in 100% of the FMM share of area. This should take place at age 3 of the second and third cycles.

Thinning

No thinning is either recommended or done in pure eucalyptus stands.

Pruning

No pruning is done or recommended.

Harvest

Harvester is used only in the case of the eucalypt area that is managed by the industry (about 20% of the total forest area). Extraction is fully mechanized (100%): skidder in areas managed by the industry and tractor with winch in the remaining areas.

Nature protection

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 676754.

The maximum contiguous harvesting area is less than 50 ha (see above, page 121) to address environmental concerns with impacts of harvests.

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ALTERFOR

II. Ranking of Ecosystem Services (ES)

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2.6. Portugal

2.6.1. Assessment of the contribution of stand-level Forest Management Models to the provision of ecosystem services in Vale do Sousa CSA.

The Vale do Sousa CSA is located in the southern part of the Sousa Valley, and extends over an area of 14,840 ha corresponding to the following ZIF separated by the Douro River: Entre-Douro-e-Sousa (north of the Douro River) and Paiva (south of the Douro River). The Vale do Sousa CSA was chosen for its representativeness of forest management practices and forest ownership structure of the North-Western Portugal forest, i.e. over 85% of the forest area in Portugal is privately owned (mostly by small non industrial private forest owners) and blue gum/ eucalypt (*Eucalyptus globulus* Labill) and maritime pine (*Pinus pinaster* Aiton) are two of the main forest species. Its forests are thus mainly dominated by eucalypt (pure and mixed), followed by maritime pine. In pure stands, it covers 2/3 of the area. In a mixture with maritime pine it grows on another 1/3. Chestnut grows on a limited area, approx. 1%. In terms of volume, the dominance of eucalypt is even more striking, approx. 90% of the volume in the CSA.

Four forest management models (FMMs) are identified in the Vale do Sousa CSA, three encompass eucalypt. The remaining area is occupied by hardwoods, mostly chestnuts (FMM 3). A mixture between maritime pine and eucalyptus characterize two different models: FMM1 and FMM2. In the case of FMM1, maritime pine is dominant, approx. 8180 m^3 (73%) and eucalyptus 3065 m^3 of the standing volume (27%). In FMM2 eucalypt is the main specie approx. 14150 m^3 (67%) and eucalyptus 7100 m^3 (33%), and FMM 4 – pure eucalypt plantations. These four FMMs cover the entire CSA.

The schedule of forest operations in these FMMs may be summarized as follows:

- The maritime pine prescriptions assumed plantations with 1,400 plants per hectare and rotations of 40 and 60 years, with thinnings occurring every five years between 20 and 50 years of age (up to 5 years before the final harvest) based on a Wilson factor (FW) of 0.27.
- The eucalypt prescriptions were plantations of 1,400 trees per ha with rotations based on three coppice cycles ranging from 10 to 14 years in length. A stool thinning option was included that leaves an average of 2 shoots per stool at year 2 of each cycle.
- Chestnut prescriptions assumed plantations of 1,250 trees per ha and alternative thinning periodicities of 5 or 10 years starting at age 15. Rotations range from 40 to 70 years.

For more details about each FMM, the reader is referred to the document ISA (Vale do Sousa) contribution to D11 Part 1 (Marques and Borges 2017)

2.6.2. Approach to characterize the contribution of each FMM to the provision of ES

Each Vale de Sousa FMM encompasses a huge number of prescriptions (e.g. alternative fuel treatment schedules, thinning regimes, rotation ages), and the variability across prescriptions (within each FMM) makes it infeasible to rank FMMs based on their contribution to the provision of

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each ES. In fact, the variability of these contributions across prescriptions within a FMM is often higher than the variability across FMMs. Further that contribution varies over time within the same prescription thus complicating further the assessment. Finally, the contribution varies also across stands. Therefore, this report will characterize the provision of ecosystem services by each FMM by a) selecting a stand that is representative of the location of each FMM in the CSA (e.g. based on site index), b) selecting a set of 4 rotations based on the range of fuel treatments' periodicity and of rotation ages that characterizes each FMM (**Fehler! Verweisquelle konnte nicht gefunden werden.**) and c) reporting the chronological sequence.

Table 33 Prescriptions used to assess the contribution of each FMM to the provision of ecosystem services in the Vale do Sousa CSA, Portugal.

FMM#	Short name	Species Forest cover (%)	Rotation range RA – rotation age	Weight (% of forest area)
FMM1	Mixed maritime pine + Eucalypt forest system	Pinus pinaster Aiton x Eucalyptus globulus Labill Maritime pine (73%)	RA = 40 years. No fuel treatments	16,00%
			RA = 40 y. Yearly fuel treatments	
			RA = 60 y. No fuel treatments	
			RA = 60 y. Yearly fuel treatments	
		Eucalypt (27%)	Cycle = 10 y. No fuel treatments	
			Cycle=10y. Yearly fuel treatments	
			Cycle = 12 y. No fuel treatments	
			Cycle=12y. Yearly fuel treatments	
FMM2	Mixed Eucalypt + maritime pine forest system	Eucalypt (67%) Eucalyptus globulus Labill x Pinus pinaster Aiton	Cycle = 10 years. No fuel treatments	17,00%
			Cycle = 10 years. Yearly fuel treatments	
			Cycle = 12 years. No fuel treatments	
			Cycle = 12 years. Yearly fuel treatments	
		Maritime pine (33%)	Rotation age = 40 years. No fuel treatments	
			Rotation age = 40 years. Yearly fuel treatments	
			Rotation age = 60 years. No	

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			fuel treatments	
			Rotation age = 60 years. Yearly fuel treatments	
FMM3	Chestnut forest system	Castanea sativa Mill 100%	Rotation age = 40 years. No fuel treatments	1%
			Rotation age = 40 years. Yearly fuel treatments	
			Rotation age = 70 years. No fuel treatments	
			Rotation age = 70 years. Yearly fuel treatments	
FMM4	Eucalypt forest system	Eucalyptus globulus Labill 100%	Cycle = 10 years. No fuel treatments	66%
			Cycle = 10 years. Yearly fuel treatments	
			Cycle = 14 years. No fuel treatments	
			Cycle = 14 years. Yearly fuel treatments	

2.6.3. Contribution of CSA stand-level FMMs to the provision of ES

This report assesses the contribution of each stand-level FMM to the provision of carbon storage, wood production, water services, cultural services, biodiversity, and regulatory services. The assessment was based on the ALTERFOR guidelines. It considered the CSA inventory data available and took advantage of the functionality of available models and decision support tools. Results are reported in separate excel files, one for each ES:

Below, we outline further the assessment framework, namely how the availability of data and information conditioned the implementation of the guidelines. For more information please check earlier reports by the Vale do Sousa CSA research team.

Biodiversity

As reported earlier there is no data or models available to quantify some specific indicators, such as: Forest Structure - Dead wood and Forest Structure - Large trees. All 4 Vale do Sousa stand-level FMMs involve an even-aged system thus no 'large trees' are left standing after a clearcut. We report data and expert scores based on tree species composition, shrub biomass accumulation, and disturbance. Ongoing research will fine tune the assessment of the contribution of shrub biomass to biodiversity.

Carbon Storage (Mg ha^{-1})

No belowground (BG) carbon storage data is available. Carbon pools reported include only aboveground biomass (AG) (i.e. all living biomass above soil including stem, branches, bark and leaves from trees with dbh above 7.5 cm).

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Cultural services

We considered the three concepts:

- Naturalness/disturbances
- Complexity
- Visual scale
- Historicity / imageability
- Ephemera

Yet there are no data or models available to address the concept Stewardship as well as to estimate the contribution to several dimensions of the five other concepts. Moreover, no model or expert knowledge is available to an overall score of concepts and dimensions.

Regulatory services - Wildfire resistance

The vulnerability of stands to wildfire criteria was assessed according to the specific stand wildfire resistance (Ferreira et al. 2015; Marques et al. 2017) that is based on wildfire occurrence and post-fire mortality probability models available in our research group (e.g. Marques et al, 2011; Garcia-Gonzalo et al. 2011).

Water services

As reported earlier it is not possible to perform a quantitative evaluation of the ES at the basic level. Our CSA can report the variation of the raw DSS outputs but the net contribution to the indicators is not provided as no model or expert knowledge is available for that purpose. Our DSS provides information regarding forest cover type, stand age distribution and harvested area in each planning period and yet we have no model nor expert knowledge to check the impact of those outputs on total supply of water per forest area, runnof time, water distribution, erosion protection and water quality either at the stand-level. The burned area was estimated using fire occurrence models (through biometric variables, percentage of shrub biomass and topographic data) developed within our research group (e.g. Marques et al. 2011). Nevertheless, we have no models or expert knowledge that might link those variables to quantify water related ES at an advancel-level.

Wood production (m^3 ha)

We report the pine, eucalypt and chestnut timber volume produced in each period, i.e. eucalypt pulpwood (m^3), pine sawlog (m^3), chestnut sawlog volume (m^3). All stands are even aged yet please note that in the case of mixed stands the harvests of eucalypt and maritime pine are performed independently, when the species reach the harvest age.

2.6.4. References

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